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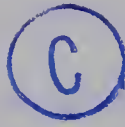
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FACIES ANALYSIS OF THE KEG RIVER FORMATION
(MIDDLE DEVONIAN) IN RAINBOW B POOL, ALBERTA

by

DIETER PFAFF, B.Sc. (G. Eng.)



A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY

EDMONTON, ALBERTA

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Facies Analysis of the Keg River Formation (Middle Devonian) in Rainbow B Pool, Alberta", submitted by Dieter Pfaff, B.Sc. (G. Eng.), in partial fulfilment for the degree of Master of Science.

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ABSTRACT

The Middle Devonian Rainbow B Pool reef complex was petrographically and paleontologically investigated by examining slabbed cores and thin sections from 8 wells. On the basis of this study, the Rainbow (reef) Member was subdivided into two informal stratigraphic units referred to as the upper and lower Rainbow Members.

The lower Rainbow Member is characterized by the presence of corals and massive stromatoporoids which form a typical organic reef complex. The member has been subdivided into 4 main facies. These include:

- A) Reef facies - wave resistant and fragmented reef builders.
- B) Back-reef facies - skeletal and non-skeletal sands.
- C) Fore-reef facies - dark argillaceous muds with fragmented skeletal remains.
- D) Basinal facies - crinoid rich muds.

The upper Rainbow Member is characterized by shallow water carbonates similar to the strand line carbonates of the Persian Gulf, Bahaman Islands, and Florida Bay. Three facies and their variants are recognized.

- A) Intertidal facies - sparsely fossiliferous laminoid fenestral carbonates and lump-pellet carbonates.
- B) Subtidal facies - fragmented fossiliferous carbonates and massive pelletal beds containing scattered stromatoporoids and corals.
- C) Lagoonal facies - finely crystalline dolomite containing the aberrant stromatoporoid Amphipora.

An early diagenetic dolomite replaces more than 90 percent of the total calcium carbonate in the reef. The dolomite replaced the calcium carbonate volume by volume, and in the process part of the framework and matrix components were

dissolved, creating voids. A white hydrothermal dolomite was introduced later. It infills pre-existing voids and obliterates original rock textures.

The geometry and paleotopography of the reef complex were studied by isopach maps, structure maps and cross sections. The prominent features shown by these maps and cross sections are: 1) a pronounced low or lagoonal portion in the centre of the upper Rainbow Member; 2) structural warping of the platform beds; 3) a steep fore-slope and a gentle back-slope for the lower reef complex.

The geologic history of the reef has been portrayed as four major stages of development, beginning with platform deposition and ending with reef burial by Muskeg evaporites. A new interpretation is presented in which it is suggested that reef growth (upper Rainbow Member) was contemporaneous with evaporite deposition (upper Muskeg Member).

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The study was undertaken at the University of Alberta under the guidance of Dr. D.E. Jackson and Dr. J.F. Lerbekmo. Dr. C.R. Stelck aided the writer in the identification of megafossils.

The writer sincerely thanks Chevron Standard Limited for supplying him with thin sections and well logs; and Banff Oil Limited for allowing free access to their cores and drill cuttings at their Core Laboratory, Calgary. Photographs of slabbed cores were also generously provided by Banff Oil Limited. Special thanks are extended to J.R. Langton and D.A. Pounder for their help and co-operation.

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INTRODUCTION

General Statement

The Rainbow Field is located in northwestern Alberta (see Figure 1) and is composed of numerous oil pools, with production from dolomitized or partially dolomitized Keg River pinnacle reefs of Givetian Age (late Middle Devonian). The reefs are located within the northern end of what is commonly referred to as the Elk Point evaporite basin.

The discovery, in 1965, of Rainbow A Pool (discovery well Banff Aquitaine Rainbow West 7-32-109-8 W.6) led to the exploration and discovery of numerous other pools. The Rainbow field as of May 1st, 1967 includes 20 separate Keg River oil and gas pools, 1 Sulphur Point oil pool and 2 Muskeg oil pools. They have been designated by the Oil and Gas Conservation board by letters in alphabetical succession (see Figure 2). Several pools are more commonly known and referred to by name, such as Saka (Keg River F pool) and Tsuhae (Keg River E pool). Recoverable oil reserves for the field likely exceed one billion barrels.

Out of the numerous pinnacle reefs in the Rainbow Field, the Rainbow B Pool was chosen for thesis study. It was chosen for the following reasons: 1) Well logs, core and samples were available at the beginning of the study. 2) Abundant core control as compared to other reefs in the area. 3) It is one of the largest reefs discovered. Unfortunately at the time the study began, the amount of limestone in the B Pool reef relative to other reefs in the vicinity was not known.

Drilling activity in the Rainbow area has been intense in the past two years, and is only now beginning to slow down. As with many newly developing regions, all well information is not available. All maps and diagrams in this report are based upon the well data information available on May 1st, 1967. (complete list given in Appendix).

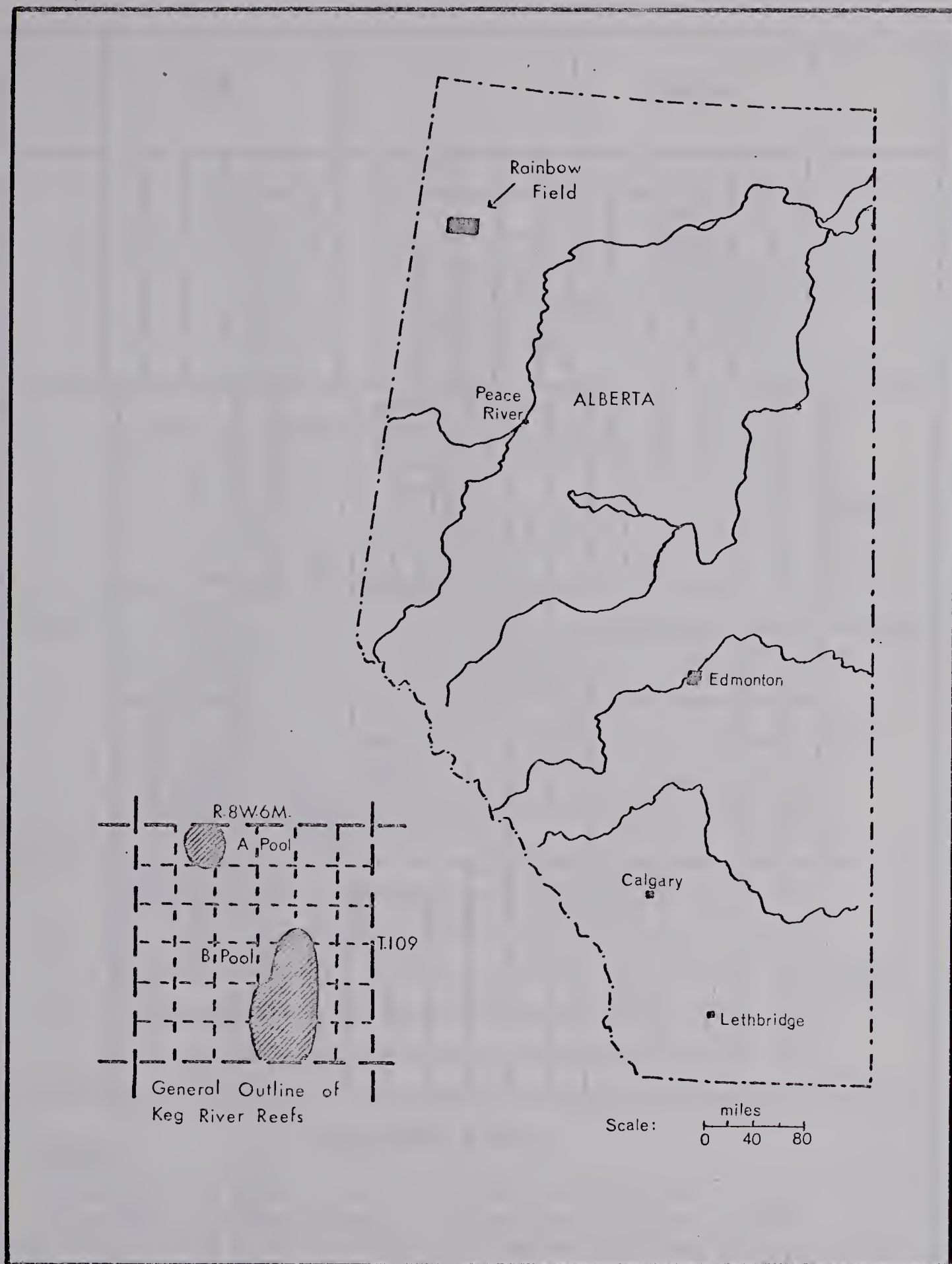


Figure 1. Location of Rainbow Field and Rainbow B Pool Reef Complex

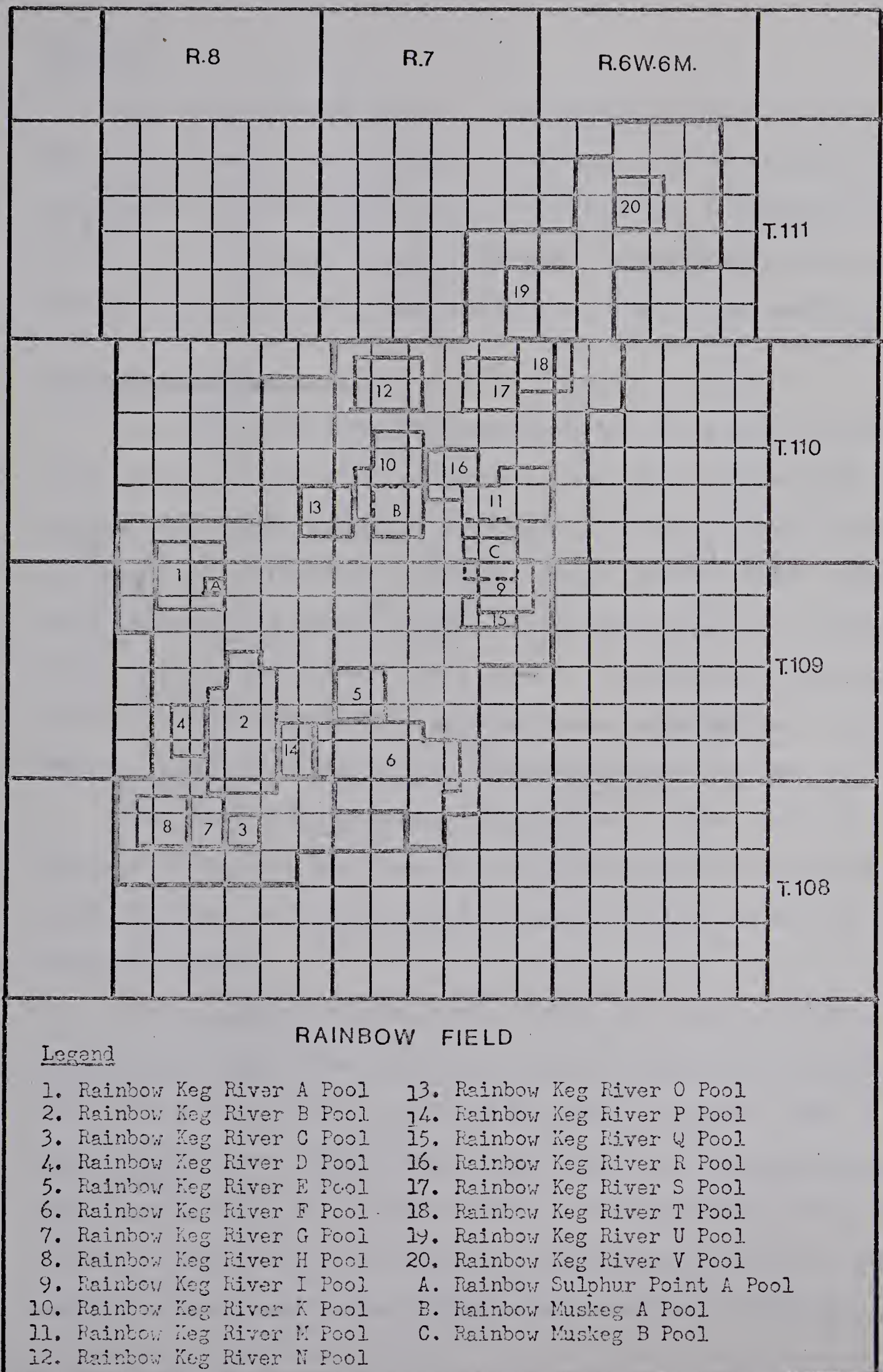


Figure 2. Outline of the Rainbow Field with designated Pools
(Effective date May 1, 1967).

Objectives

This study describes and gives an environmental interpretation of the facies within the reef complex. Special attention is devoted to: (a) the distribution of various organisms and rock facies throughout the reef complex, and the depositional environments they represent; (b) the relationship of the reef complex to the enclosing evaporite sediments; (c) discovering what initiated, restricted, and ended reef growth.

Nomenclature and Age

Law (1955) published the first comprehensive work on the geology of northwestern Alberta. The formational nomenclature introduced at that time is still valid (see Figure 3). New terminology and slight revisions of Law's work were introduced by Belyea and Norris (1962) and by Grayston, Sherwin, and Allan (1964). Hriskevitch (1966) subdivided the Keg River Formation into three formal members - the Lower Keg River, Upper Keg River and Rainbow Members. The Black Creek Member was proposed for the lower portion of the Muskeg Formation. The formational nomenclature as presented by Hriskevitch (1966) will be adopted here (see Figure 3).

The presence of Stringocephalus cf. obesus (Plate 1, Figure 1) in the Rainbow Member of the Keg River Formation in the Banff Mobil Rainbow West 10-32-109-8 W.6 well (at 6036 feet, about 140 feet from the top of the formation) confirms a Givetian Age for this member.

The Stringocephalus from the Rainbow Member most closely resembles the Stringocephalus obesus Grabau taken from the top of the Middle Devonian section at Mt. Burgess, Porcupine River, northern Yukon (Warren and Stelck, 1962). The Stringocephalus from the Rainbow Member is not identical with the Stringocephalus obesus obtained from the Winnipegosis Formation of Manitoba as illustrated by Warren and Stelck (1962). Assuming the validity of the faunal sequences based on stringocephalids, set up by both Crickmay (1960) and Warren and Stelck (1962), the upper

LAW 1955		BELYEA & NORRIS 1962		GRAYSTON, SHERWIN & ALLAN 1964		THIS PAPER after HRISKEVICH 1966	
Watt Mt.		Watt Mt.		Watt Mt.		Watt Mt. Fm.	
Muskeg	Presqu'ile	Sulphur Point		Muskeg	Presqu'ile	Sulphur Point Fm.	
		Muskeg				upper member	
Keg River	ELK POINT	Keg River	Keg River	Keg River	UPPER ELK POINT	Muskeg formation	Rainbow Member
						Keg R. Fm.	
Chinchaga	ELK POINT	Chinchaga	Chinchaga	Chinchaga	UPPER ELK POINT	Lower Keg River Mbr.	
						Chinchaga Fm.	
Red Beds	ELK POINT	Pre-Chinchaga Beds	Cold Lake	Ernestina Lk.	LOWER ELK POINT	Cold Lake Fm.	
						Ernestina Lk. Fm.	
Precambrian	Precambrian	Precambrian	Precambrian	Precambrian	Precambrian	Basal Red Beds	
						Basal Red Beds	
Precambrian		Precambrian		Precambrian		Precambrian	

Figure 3. Formational Nomenclature of the Lower and Middle Devonian of Northwestern Alberta

portion of the Rainbow Member would correlate with the Pine Point Formation of the Great Slave Lake region.

Reef Terminology

The terms and definitions used in this study follow Klovan (1964), namely:

Reef - rigid carbonate structures with vertical dimensions significantly larger than the contemporaneous sediments, composed, at least in part, of organisms able to build and maintain the structure as a topographic feature on the sea floor and potentially in the zone of wave action.

Reef Complex - the aggregate of reef limestones and related carbonate rocks.

Organic Reef - that portion of the reef which is or was built directly by organisms, and is responsible for the reef's wave resistant character.

The definitions listed above are applicable in subdividing the Rainbow Member into two informal stratigraphic units; a lower organic reef complex, and an upper algal reef complex. These divisions provide a convenient way of discussing the depositional history of the Rainbow Member.

The lower complex is classified as organic reef only in so far as it has an outer portion that is responsible for its wave resistant character. The normal association of fore reef detritus (sediments derived from the organic reef and deposited seaward from it), back reef detritus (sediment of the same origin deposited behind it) and sediments deposited within the reef, are all present. The entire sequence of sediments is genetically related and is hence referred to as an organic reef complex.

The limestones and dolomites in the upper portion of the Rainbow Member cannot be classified as an organic reef complex since very little rigid organic skeletal framework is present. The sediments are predominantly shallow water carbonate sands, silts and muds which were deposited in a regime similar to the carbonates forming at present in the Bahamas, Florida Keys and Persian Gulf. For this reason some workers might not consider the term reef applicable. However, the writer considers the term algal reef complex appropriate since algae were responsible for building and maintaining topographic features, which may have formed in the zone of wave action.

The lower organic reef complex and the upper algal reef complex are hereafter referred to as the lower and upper Rainbow Member respectively.

STRATIGRAPHY

The Elk Point Group forms the basal unit of the Devonian System in western Canada. It consists of a sequence of carbonates, evaporites and clastics of predominantly Middle Devonian age. The Elk Point Group has been subdivided into the Lower and Upper Elk Point Subgroups (Grayston et al., 1964) with the boundary between the subgroups being placed at the base of the Keg River Formation. This boundary may also approximate the Givetian-Eifelian boundary.

In the Rainbow Lake region, the Elk Point Group is about 1500 feet thick. It lies unconformably on Precambrian rocks, and is overlain possibly disconformably, by Upper Devonian carbonates (Slave Point Formation).

Lower Elk Point Subgroup

The Lower Elk Point Subgroup in western Canada is predominantly an evaporitic sequence. The sediments which constitute the subgroup were initially deposited in three distinct basins; the Central Alberta Basin, the Northern Alberta Basin and the Southern Mackenzie Basin. These three basins slowly expanded and finally merged, forming a single enlarged basin (Elk Point Basin). The subdivisions established for the Lower Elk Point Subgroup in the Rainbow Lake area include the Basal Red Beds, the Ernestina Lake, the Cold Lake and the Chinchaga Formations. These have been discussed by Hriskevitch (1966) and will not be elaborated upon further.

Upper Elk Point Subgroup

The Upper Elk Point Subgroup is represented by widespread deposits of evaporites and carbonates. Clastic rocks border the highlands. The carbonates are commonly

reefoid and to a large extent control the depositional environments. The thickness of the Upper Elk Point Subgroup is variable, with a maximum thickness of approximately 1100 feet being attained in the Rainbow Lake region.

Paleogeography

The deposition of the Lower Elk Point began with the slow submergence of the craton. The sea entered from the northwest, flooding the main part of the Elk Point basin as far south as the Meadow Lake Escarpment (see Figure 4). The sediments were initially deposited in three distinct basins which were separated from each other by the Tathlina High and Peace River Arch. Deposition in the basins did not begin simultaneously but began in the Central Alberta Basin (deposition of Lotsberg salt) and later in the North Alberta Basin (deposition of Ernestina Lake Formation) and Mackenzie Basin (deposition of the Bear Rock anhydrite and carbonates). Continued subsidence resulted in the merging of the three basinal areas which was accompanied by widespread deposition of the Chinchaga Formation.

The deposition of the Lotsberg and Cold Lake salts, and the Chinchaga anhydrites required highly saline conditions. The presence of normal marine carbonates to the northwest (in the area of Fort Nelson Uplift) suggests the presence of some sort of barrier (reef?).

Following the deposition of the Lower Elk Point the seas transgressed across the continent from the north, drowning the barrier. This gave rise to formation of normal marine shelf type carbonates of the Lower Keg River Member (reef platform). With the establishment of a normal marine environment, reefs began growing along the margins of land blocks, while patch reefs developed farther offshore.

The thickest and most complex accumulation of carbonates is encountered in northwestern Alberta (see Figure 5). The carbonate complex, which may be composed of either carbonate banks or reefs, surround areas of local down-warps (related to faulting) and, as such, may be classified as sub-basins or grabens. In the centres of these sub-basins isolated pinnacle reefs grew.



Figure 4. Paleogeography of PreChinchaga (A) and Chinchaga Formations (from Grayston, Sherwin, and Allan, 1964, Figures 5-11A and 5-11B).

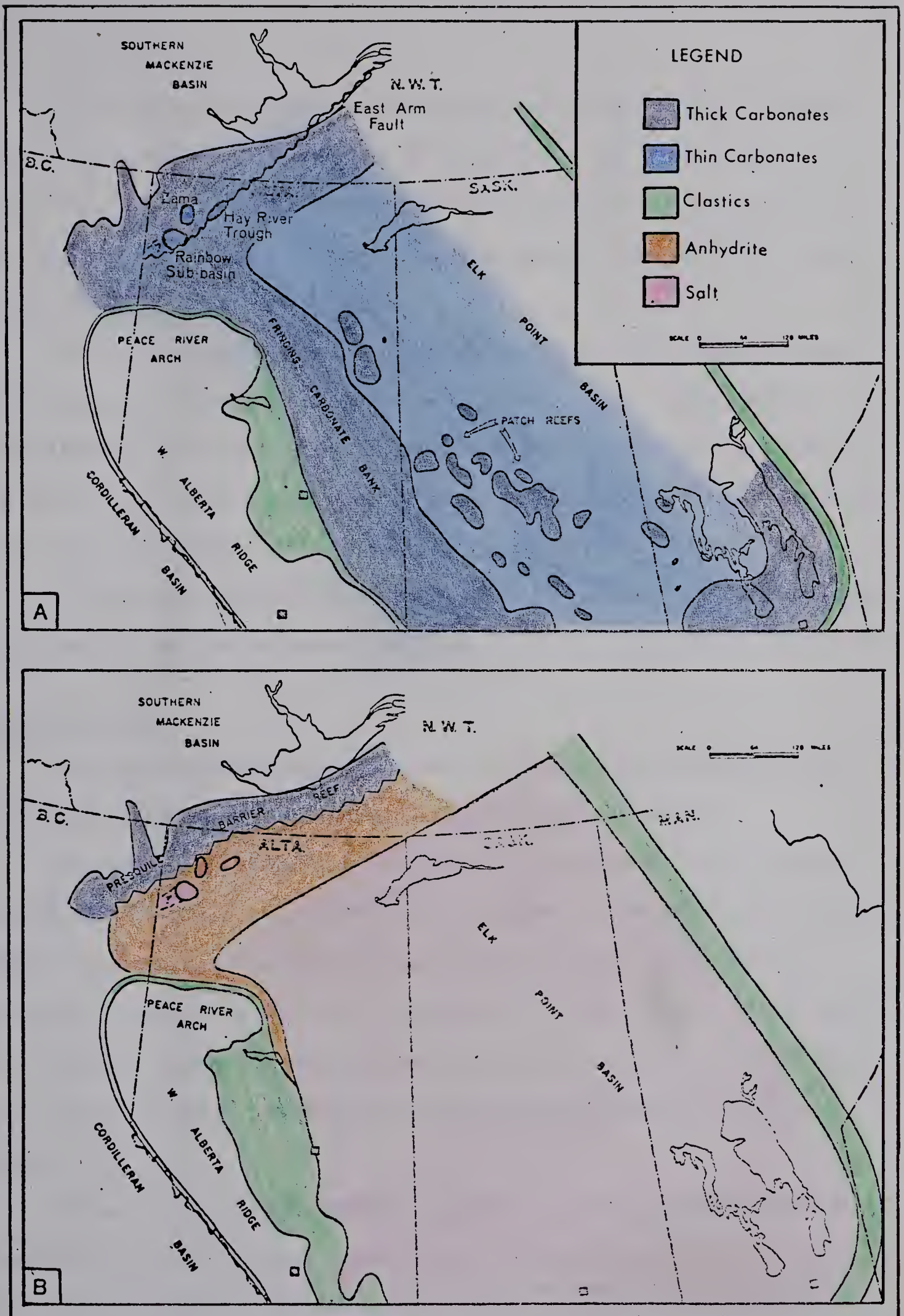


Figure 5. Paleogeography of the Keg River Formation (A), and Muskeg-Presqu'ile Formations (B). Modified from Grayston, Sherwin, and Allan (1964).

One of the most significant structural features in northern Alberta is the Hay River Graben which formed along a Precambrian fault zone that can be traced from the surface at Great Slave Lake (East Arm Fault) into the subsurface as far south as Rainbow Lake. Other regions with high rates of subsidence include the Rainbow Sub-basin and Zama Sub-basin (see Figure 5).

Continued reef growth resulted in the formation of a complex barrier reef. The barrier appears to have linked submerged topographic highs, namely the Fort Nelson Uplift (in east central British Columbia) with the Tathlina Uplift (in the Northwest Territories). The establishment of the barrier reef resulted in restricted conditions which led to the deposition of the Muskeg salts and anhydrites.

Elk Point sedimentation ended with the deposition of the Watt Mountain clastics and the return to more normal marine conditions.

Rainbow Sub-basin

The Rainbow Sub-basin occupies an area of approximately 1200 square miles and is completely surrounded by carbonate banks or reefs (see Figure 6).

The western edge of the basin is rimmed by the main barrier reef (Presqu'ile Formation?). The presence of a fairly continuous barrier is attested to by the striking difference of facies on either side of the reef complex, namely, evaporites on the south and east, and marine shales and carbonates in the north and west. At the present time, there is no evidence to suggest discontinuity in the barrier such as in the Leduc-Rimbey chain, or even on a much smaller scale, but future exploration could prove otherwise.

The southeastern edge of the basin is rimmed by a carbonate bank or reef which formed along an area of major structural activity. The "reef" formed over an area of discontinuous structural highs (block faults) trending in a north easterly direction as

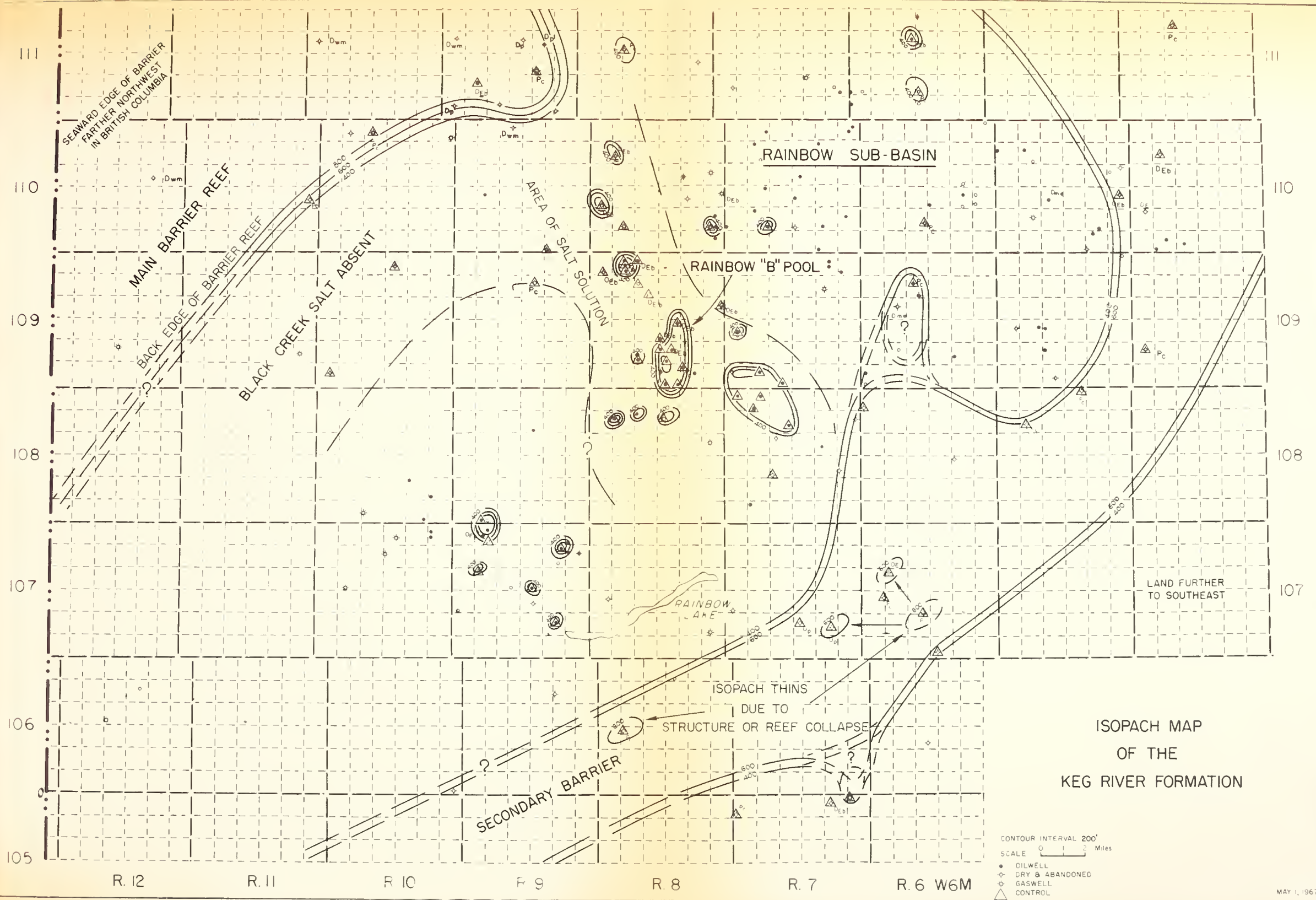


Figure 6.

can be seen on the structure contour map on top of the Chinchaga Formation¹ (see Figure 7). Coincident with the structural highs are remnant knobs² of pre-Devonian meta-sediment (predominantly quartzite and silicified arkoses). A more complete study will be required to establish the relationship of the underlying meta-sediment knobs to faulting and overlying reefal development. At present the study is hampered by the lack of information, since many of the wells are still on the confidential list.

The southwestern portion of the basin lacks control, and hence the extent of the basin in this direction is not known. The relationship of the Rainbow Sub-basin to the more northerly Zama Sub-basin is also uncertain at the present time.

In the centre of the basin there are numerous isolated pinnacle reefs³ having an areal extent of about one quarter to 7 square miles. The larger ones appear to have associated lagoonal areas similar to present day reef atolls. The thickness of the reefs (Rainbow Member only) is also variable, ranging from 800 feet (7-18-109-7 W.6) to 280 feet (4-9-109-8 W.6). The majority are dolomitized, with vestiges of limestone occurring only in the upper portions. A few have escaped dolomitization entirely, notably Tsuhae (7-18-109-7 W.6). Enclosing the reefs are the evaporites of the Muskeg Formation. A diagrammatic cross section (see Figure 3) illustrates the relationship of the various stratigraphic units within the Rainbow Lake region.

The removal of Black Creek salt by solution complicates the stratigraphy and structure in the Rainbow Lake area (see Figure 9). The majority of the solution is post-Slave Point in age.

¹ The greater part of the structure in the southeast end of the Rainbow Sub-basin is post reef growth, but faulting is thought to have been initiated prior to reef growth and continued throughout most of the Devonian. Structure in the centre of the basin is predominantly prior to Wati Mountain deposition.

² Wells in which meta-sediments have been observed include 13-36-105-7 W.6, 2-16-107-6 W.6 (absent in nearby 16-18-107-6 W.6), 6-29-108-5 W.6, 6-28-111-4 W.6.

³ Many more isolated reefs occur in the Rainbow Sub-basin than are shown in Figure 6. Unfortunately no information is available (as of May 1st, 1967) regarding the thickness of these reefs.

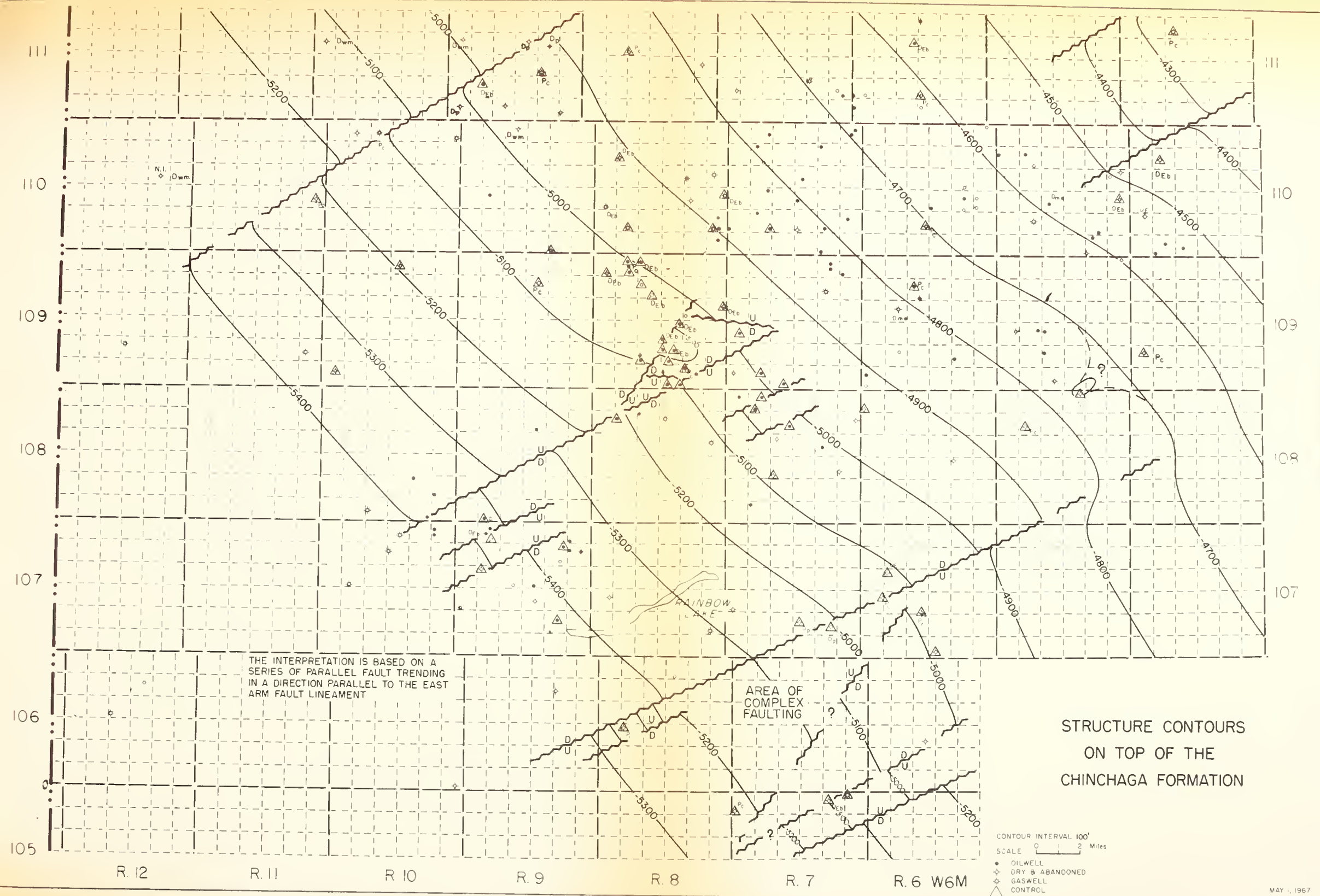


Figure 7.

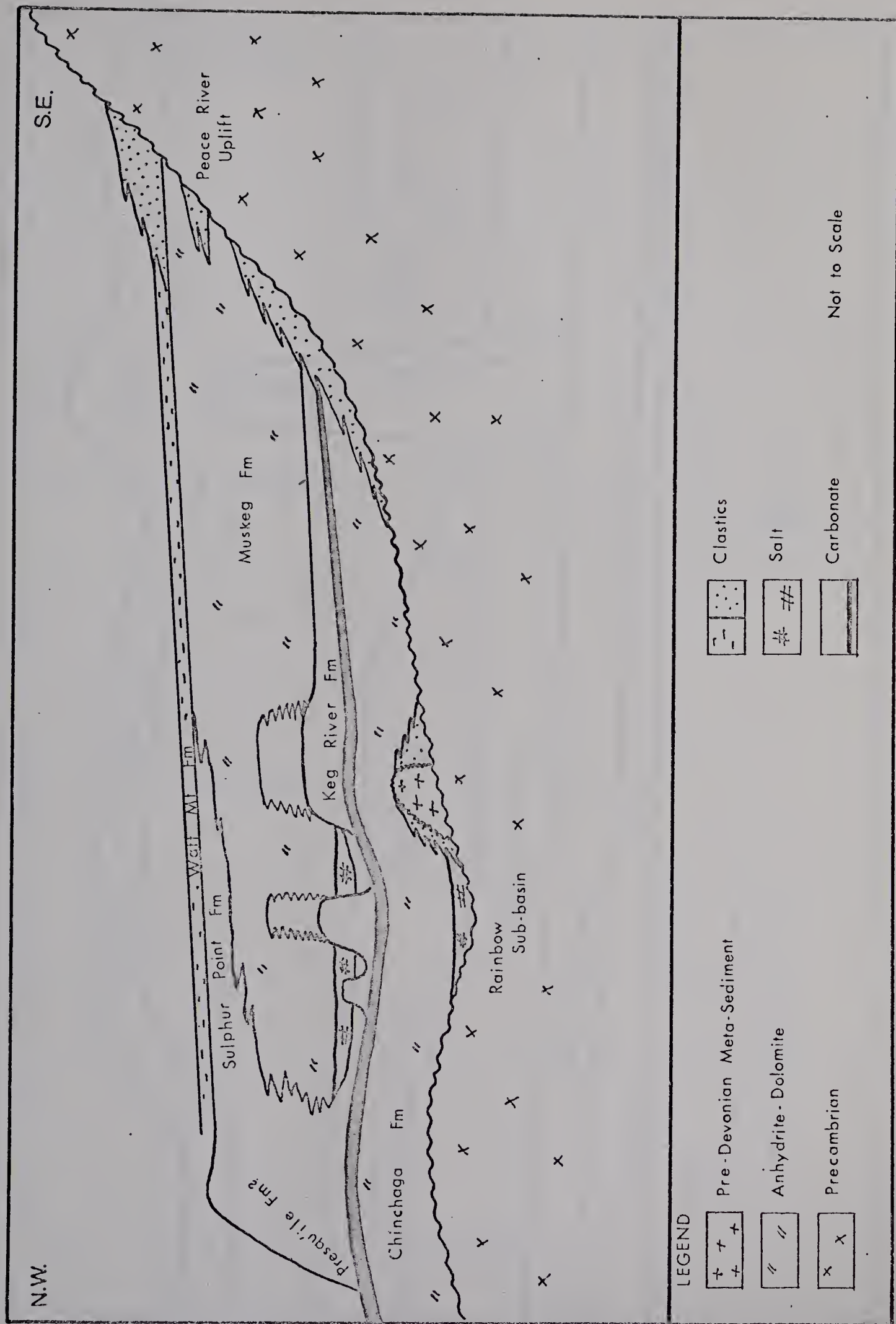


Figure 8. Diagrammatic Cross Section through Rainbow Sub-basin

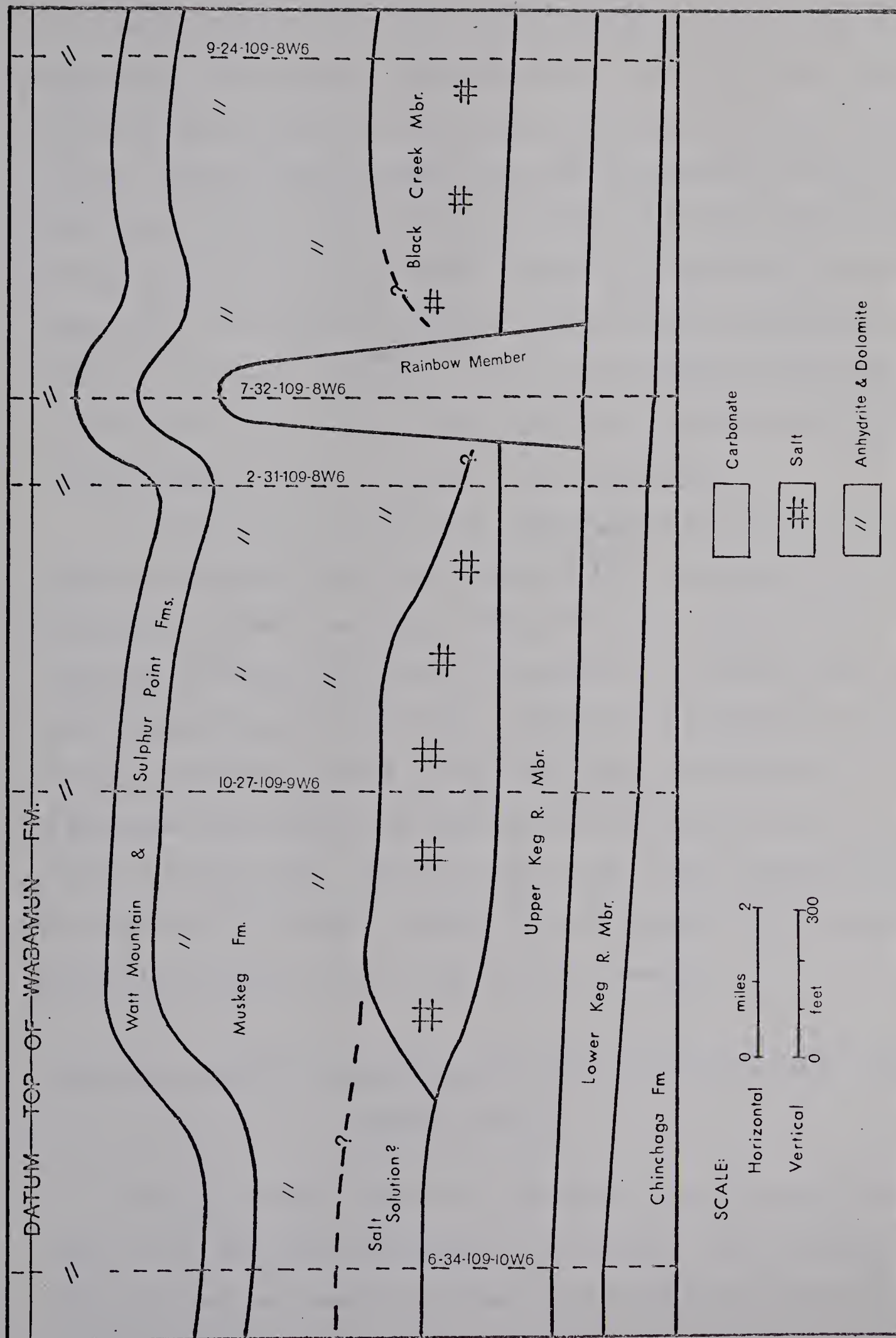


Figure 9. Stratigraphic Cross Section of the Upper Elk Point Sub-group, Rainbow Sub-basin

Solution channels are prevalent, the most notable one having formed along the back edge of the main barrier reef (see Figure 6). The areas of solution appear partially related to porosity in the underlying Keg River Formation (Upper Keg River Member). Where the member is porous some solution has taken place but where it is tight or dense little or no solution occurs. No doubt other factors are also responsible for the present day distribution of the salt. The removal of salt finds expression in the isopach maps, as for example the thinning in the Watt Mountain (or Slave Point) to Chinchaga interval and a corresponding thickening of the Wabamun to Watt Mountain (or Slave Point) interval. The structural configuration on top of the Watt Mountain is highly complex and reflects in part the solution of this salt unit.

It is interesting to note that if the complete removal of salt occurred over wide areas in northern Alberta prior to the completion of Muskeg deposition, there would be no anomalous structures or thickening to indicate the previous presence of salt. There is no reason why the salt could not have been deposited over wide areas (Black Creek salt is also found in the Hay River Trough or Sub-basin) and subsequently removed. This would mean that the salt that was deposited in the Rainbow Sub-basin is related in part to the Prairie Evaporite salts deposited farther to the south and east in the Elk Point Basin (see Figure 5B). The fact that the salt occurs only in isolated basins in the northwestern part of Alberta, indicates that local conditions led to the preservation of the salt in these areas while salt removal occurred elsewhere.

STRUCTURE, GEOMETRY AND PALEOTOPOGRAPHY OF THE KEG RIVER FORMATION, RAINBOW B POOL

The Keg River reefs of northwestern Alberta have a much more restricted areal extent than the Swan Hills and Leduc age reefs of Alberta. In plan, the largest isolated Keg River reefs encountered to date are the B Pool and Saka Pool covering

about 4 and 7 square miles respectively. This compares with 230 square miles for Redwater (Leduc Formation) and 50 square miles for Judy Creek (Swan Hills Member, Beaverhill Lake Formation).

In plan, the B Pool reef is an elongate, tear-drop shaped carbonate complex as outlined in Figure 10. The slopes of the flanks are steep, in the order of 10 degrees. However this estimate of slope is conservative, as well control is sparse near the margins of the reefs and it would not be unreasonable to anticipate dips in the order of 20 degrees. The thickness of the reef (see Figure 10) reflects structural control. Where the Chinchaga Formation is structurally low, the thickest values of reef and platform are encountered.

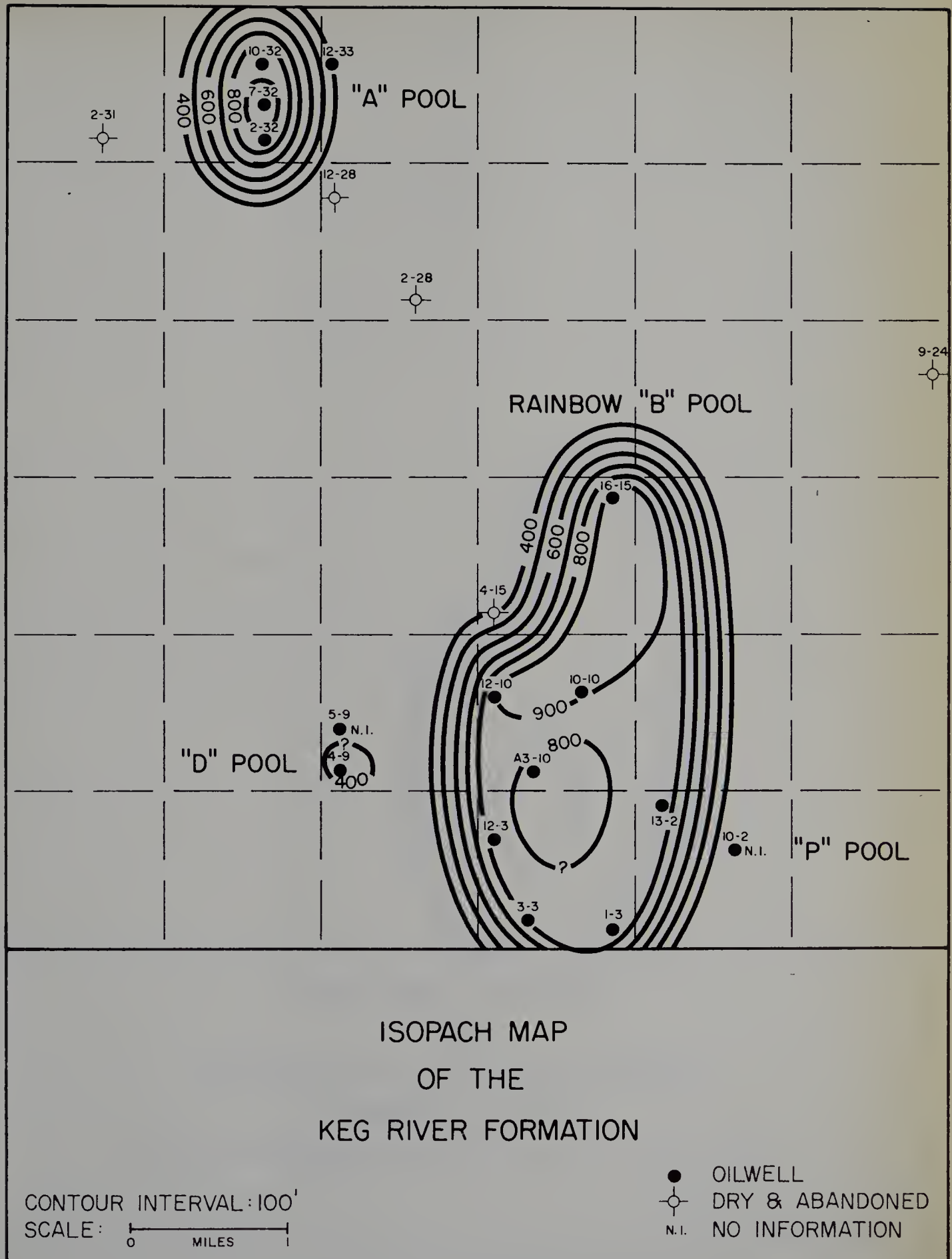
The paleotopography of the reef complex was determined by removing the regional southwesterly dip of 25 feet per mile (taken from structure contours on top of Chinchaga Formation) from a standard structure contour (morpho contour) map (see Figure 11). Deriving a contour map in such a manner compensates neither for any original dip existing in the basin prior to tilting, nor reef compaction and collapse. The effect of initial dip in the basin is considered to be negligible¹ due to the small areal extent of the reef, while the amount and effects of compaction are at best difficult to evaluate. Reef collapse can be evaluated by examining the thickness of the overlying sediments (Watt Mountain to the top of the Keg River Formation).

Upper Rainbow Member

The top of the reef is a relatively flat, plateau-like surface. The cross sections of Figure 13 show this flat-topped nature and also indicate that the southern portion is somewhat lower than the northern end (40 feet between 16-15 and 1-3 wells). This is also reflected by a significant change in the sediment character in the northern and southern parts of the reef. A pronounced low area also exists in the

¹ Presently there is considerable structure at the base of the reef, but it does not appear to affect the paleotopography of the upper or lower Rainbow Members. Initial basin dip would not be negligible if one were to consider the early development and configuration of the reef.

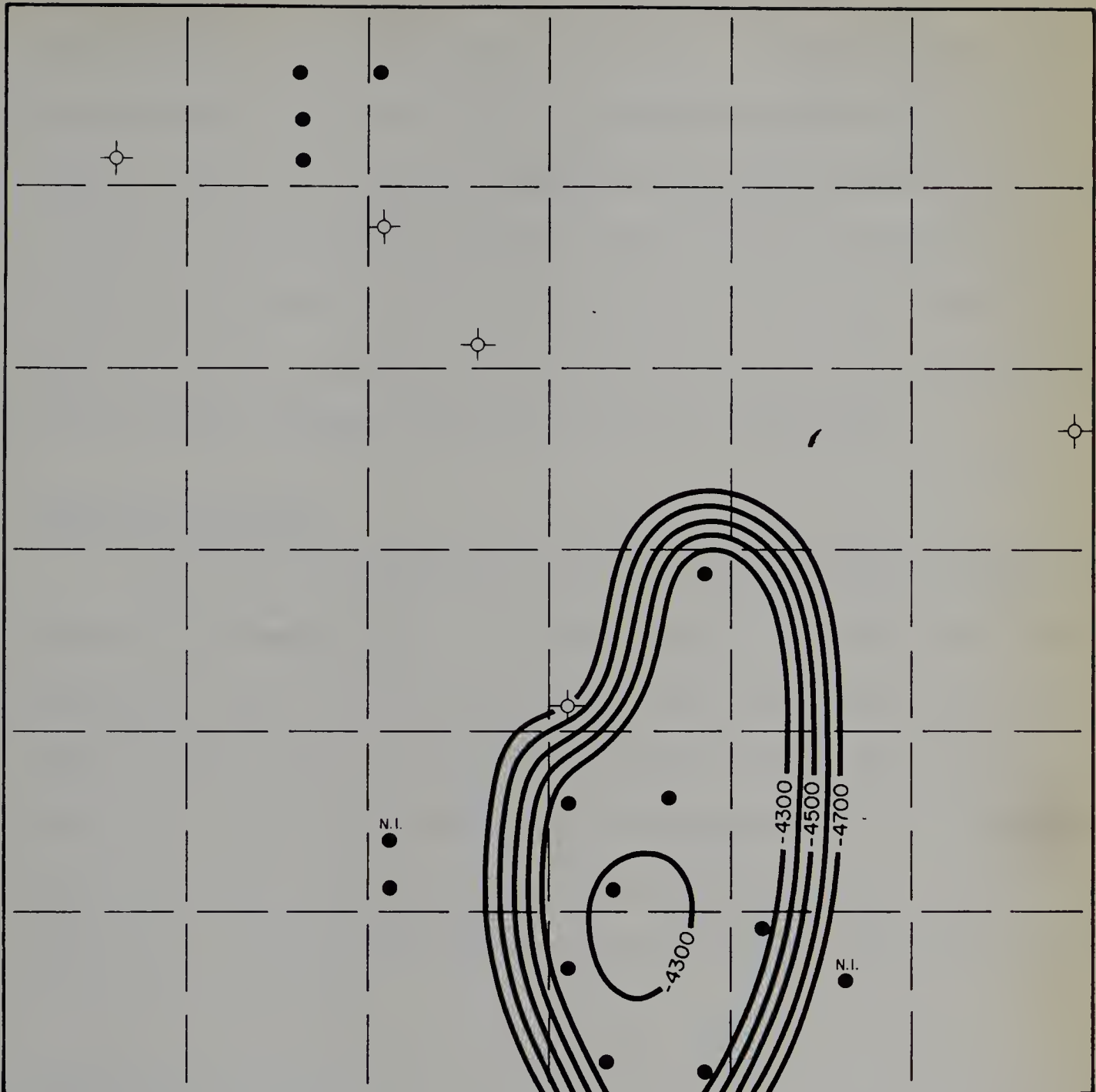
R. 8 W6M



T. 109

Figure 10.

R. 8 W6M



T. 109

STRUCTURE CONTOURS
ON
RESTORED TOP RAINBOW MEMBER
RAINBOW "B" POOL

(BASED ON A REGIONAL DIP OF 25 FEET PER MILE IN A S. 45° W. DIRECTION)

CONTOUR INTERVAL: 100'

SCALE: 0 MILES 1

● OILWELL
⊕ DRY & ABANDONED
N.I. NO INFORMATION

Figure II.

southern half of the reef, around the A3-10 well. This may be interpreted as a lagoon, re-entrant, or post Watt Mountain reef collapse feature. There is no indication seismically that a re-entrant is present in this region. The sediments of the upper Rainbow Member for the A3-10 well do not indicate reef collapse, but instead, indicate a lagoonal environment. An isopach of the overlying sediments (see Figure 12) reveals a slight thickening, indicating that this area was somewhat low prior to Watt Mountain deposition, and probably at the time the reef was growing. The overlying Watt Mountain - Sulphur Point sediments are also structurally low, suggesting that some collapse (together with drape) may also have taken place.

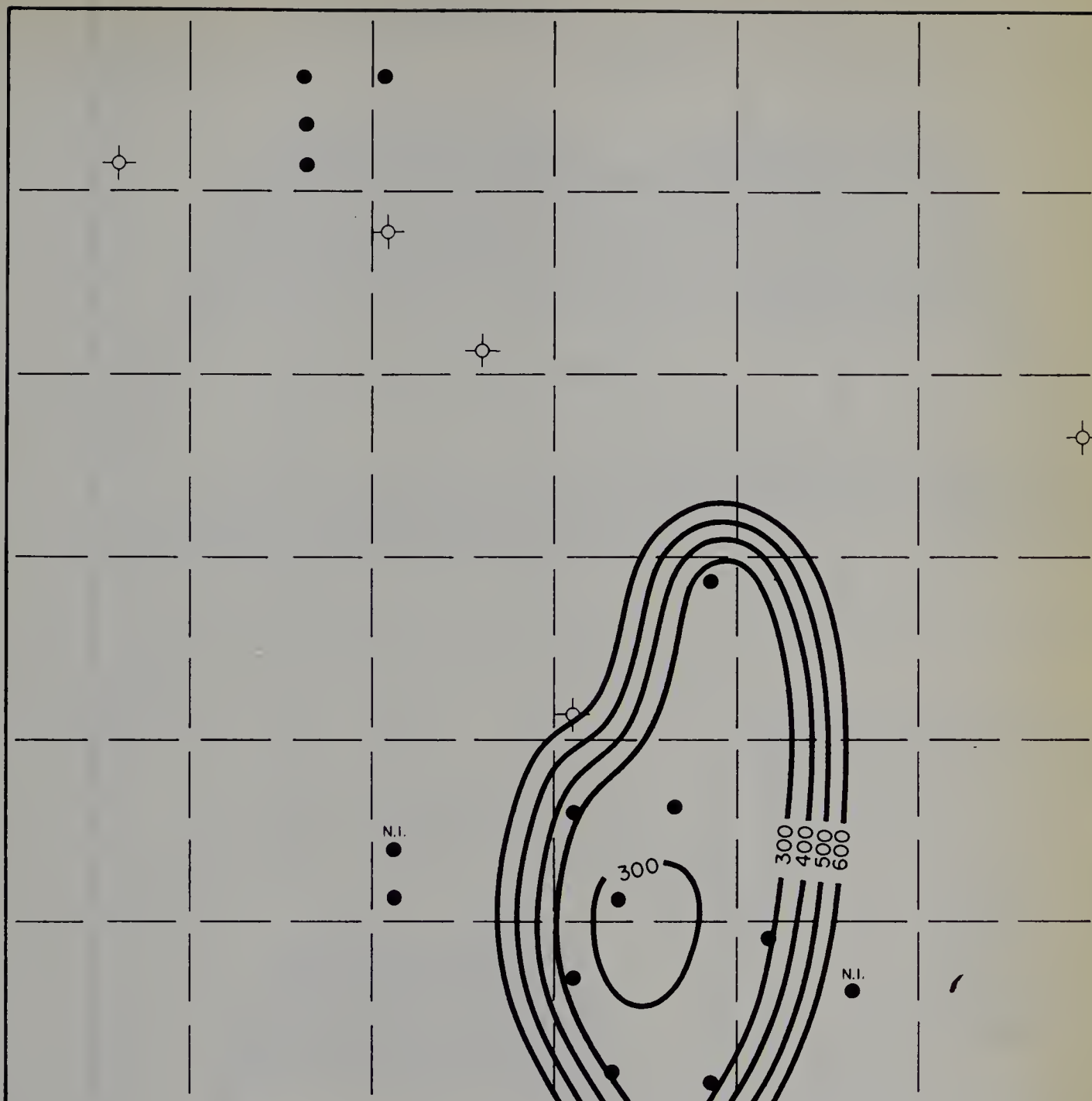
Lower Rainbow Member

A cross section of the Rainbow reef (see Figure 13) indicates a wedge-shaped carbonate mass thinning southeastwards. The steepest portion of the reef is along the northwestern margin, with more gentle slopes occurring on the southeastern side. The paleotopographic maps and cross sections suggest that the northwestern margin was at a higher elevation than the southeastern end at the time of burial. This also corresponds to the thickest portions of the reef, suggesting that this was the area of most active reef growth. Prevailing northwesterly winds could be responsible for the more active reef growth in this region.

Lower Keg River Member

The Lower Keg River Member forms the platform on which pinnacle reefs developed. Under the B Pool reef, the thickness of the member appears to be a function of structure. The platform is thin (about 110 feet) in some, but not all of the structurally high wells, and thick (about 150 feet) in the structurally low wells. This suggests that the warping of the platform began prior to its deposition in some areas, and post-deposition in other portions. All of the structure at the base of the reef seems

R. 8 W6M



T. 109

ISOPACH MAP
WATT MOUNTAIN FORMATION
TO
TOP RAINBOW MEMBER

CONTOUR INTERVAL: 100'
SCALE: 0 1 MILES

● OILWELL
⊕ DRY & ABANDONED
N.I. NO INFORMATION

Figure 12.

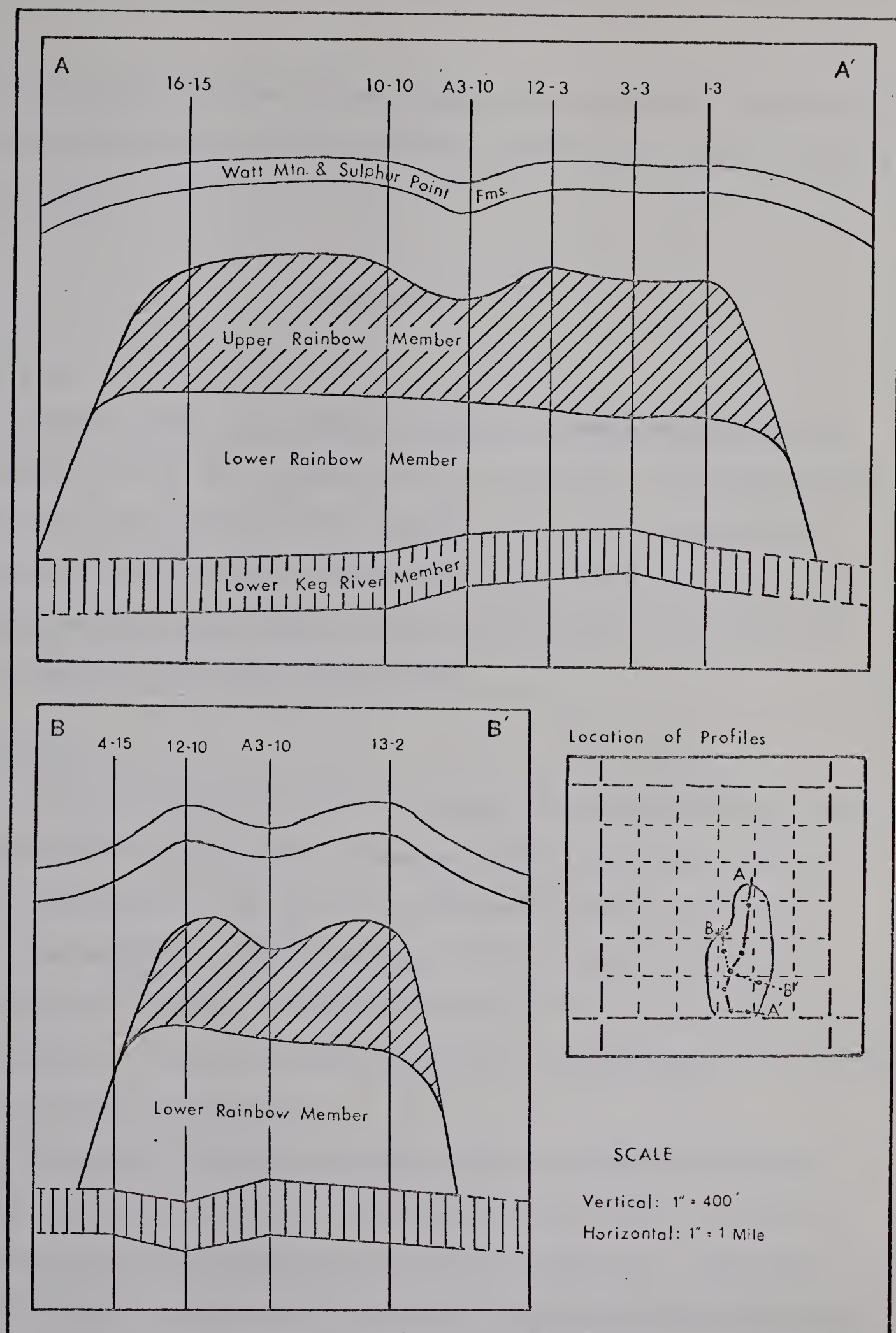


Figure 13. Paleotopographic Profiles of the Rainbow B Pool Reef Complex

to have formed prior to the end of lower Rainbow Member deposition. Paleotopography on the top of the platform was in all probability responsible for the start of reef growth at this locality.

PETROGRAPHY

Technique

The petrographic study consisted of detailed microscopic examination of all the slabbed core available. Selected surfaces of the slabs were covered with glycerine to help bring out the textural details. In addition thin sections were examined at two-foot intervals for the wells 3-3-109-8 W.6 and 13-2-109-8 W.6, together with particular interesting and principal rock types in the remaining wells. Where core was not available, drill cuttings were examined.

Classification

The description and classification of limestones has largely been based on the type and relative amount of textural components present, such as grains, lime mud, cement and pore space. At present no one classification appears to solve all the problems encountered in carbonate petrology. It is for this reason that carbonate petrographers have modified existing classification to suit their own particular studies. The resulting non uniformity necessitates discussion of the terminology and classification used in the study of carbonate rocks.

The textural classification proposed by Leighton and Pendexter (1962) has been partially adopted in this study. Modification is related only to the limits and definitions of the textural components composing the classification. Unfortunately this classification neglects to differentiate between the sizes of the constituent grains involved. Klován (1964) stressed the importance of recognizing the type of coarse

component (greater than 2 mm) present, or of noting its absence when classifying limestones. The writer agrees with Klován that these criteria are significant in the interpretation of depositional environments, especially when dealing with reef and reef detrital rocks.

Constituents larger than 2 mm

The framework constituents can be subdivided into two major categories: skeletal and non-skeletal (lithoclasts). Lithoclasts or rock fragments are important constituents locally, but in general are not very abundant. The lithoclasts are only associated with conglomerates or breccias, where the matrix is usually of slightly different composition. The skeletal constituents include all megascopic fossils. They include the great bulk of the framework constituents in the Rainbow Member. Volumetrically, the majority of skeletal grains (greater than 2 mm) occur in the lower Rainbow Member, the upper Rainbow Member being noticeably deficient in such grains. When considering the organic frame builders, an effort was made to determine whether they had been transported or were in actual growth position. The origin of many particles greater than 2 mm can often be determined in general terms only, due to the obliteration of detail through dolomitization. The identity of much biogenic material is lost through leaching, and recognition is restricted to the identity of fossil molds.

Constituent Grains (0.062 - 2 mm)

a) Skeletal components - This includes all recognizable skeletal fragments. Algae and calcispheres can be included in this category.

b) Non-skeletal components - These include oolites, pisolites, coated grains, detrital grains, lumps and pellets. Those not discussed follow the definitions as listed by Leighton and Pendexter (1962, p. 59).

Algae

Stems and branches of Dasycladacian algae (Plate 1, Figure 5) have been recognized in some of the laminated sediments in the upper Rainbow Member.

Some skeletal grains contain coatings of vague laminar finely crystalline dolomite which are presumed by their shape, form, and laminations to be of algal origin.

Calcspheres

Calcspheres are "hollow spheres, most of which are furnished with varying forms of peripheral appendages; the true sphere wall is always darker than either the investing matrix or the contents of the spherical cavities when examined by transmitted light" (Williamson 1880, p. 521).

Within the Keg River reef, calcspheres (recognizable only in the limestone portions) display a variety of shapes and features. They are commonly spherical but occasionally appear pentagonal to hexagonal in outline. Their size is variable, but usually average about 100 microns in diameter. They have a dark outer wall which also varies in thickness. The central portion is usually completely filled with a mosaic of clear calcite crystals (optically orientated). In some instances, a void occurs in the central portion. In several of the larger forms, spines protrude from the outer wall.

The great variety of shapes and morphological features are thought to be related to the degree of preservation.

Pellets

"Rounded, spherical to elliptical or ovoid aggregates of microcrystalline calcite ooze, devoid of any internal structure" (Folk, 1959). Following Klován (1964) no size limit is placed on pellets. Pellets are commonly acknowledged to be of polygenetic origin, but many workers have emphasized a fecal origin. Folk (1959) stresses the fecal origin, and in so doing implies that such agencies as algae, diagenesis

and accretion are of minimal importance. Wolf (1965) interprets most of the pellets in the Nubrigyn complex of New South Wales as having an algal origin. The mechanism for their formation is well documented and illustrated.

Both algal and fecal origins for the pellets are favoured in this study. The criteria which suggests an algal origin are the association with poorly sorted sediments containing calcispheres, scattered algal filaments, algal lumps and laminoid fenestral structures. These pellets commonly have a vague lamination or coating. Fecal pellets are suggested by indirect evidence of organic activity (burrowed sediments?). Unfortunately it is impossible in many instances to distinguish the different types of pellets.

Lumps

Lumps are composite or structureless grains believed to have formed by a process of aggregation. They are usually quite large and of irregular shape as compared with pellets. They are considered to be formed as discrete grains which became cemented together to form a "lump" after lying in contact with each other on the sea bed (Illing, 1954). The term lump as used here included the term intraclast as defined by Folk (1959). It has not yet been demonstrated that an intraclast as proposed by Folk can be differentiated from a lump in ancient sediments. Lumps are forming, recent examples being bahamites and grapestone while intraclasts (formed by the tearing up of partially consolidated lime mud and redepositing them to form a new sediment) have not been found to form in modern carbonate environments.

The lumps of the Rainbow Member are of diverse size, shape and internal structure. Although some have internal cellular structures indicating an algal origin (Plate 2, Figure 1), the majority are structureless providing little indication of their origin. It is suggested that the aggregations process described by Illing (1954) may have been responsible for their formation.

Groundmass (less than 0.062 mm)

This category includes micrite or carbonate sediment with grains less than 0.062 mm, sparite or cement, and accessory minerals. The size limit imposed on micrite (less than 0.062 mm) follows Folk's (1959) original definition but differs from Leighton and Pendexter (1962).

Sparite includes all clear, translucent calcite that occurs as a void-filling cement or recrystallization product. Crystal size is not critical to the definition.

Accessory minerals include chert, argillaceous material, pyrite, anhydrite and dolomite (in limestones).

Porosity can be considered as a separate entity or be included under this heading.

Dolomites

The classification of carbonate rocks which have been altered is based on the recognition of the original rock constituents and textures, and where this is impossible on the degree of alteration. This system shall be adopted for all the dolomite rocks encountered (Table 1). Wherever possible the original rock type is designated as per Leighton and Pendexter (1962). Where the degree of dolomitization is severe and the original rock type cannot be deduced, a grain size classification similar to that proposed for limestones (Grabau, 1913) will be used (Table 1), and modified to coincide with Wentworth (1922). Modifiers such as colour, porosity, impurities and general appearance (refer to Table 2) will precede the grain size terminology to further differentiate rock types. In some instances textures have been completely obliterated by a late stage coarse white dolomite. It is found both replacing and in-filling voids in previously formed dolomite. It occurs in various forms which are useful for descriptive purposes. This is discussed in the following section.

TABLE 1
Dolomite Classification

Degree of Alteration	Original rock type can be determined	Original rock type cannot be determined
More than 50% dolomite	Pellet Dolomite Skeletal Dolomite	Light brown mottled medium crystalline dolomite
Less than 50% dolomite	Dolomitic Pellet-micritic Limestone	Dolomitic limestone (not encountered)

TABLE 2
List of Modifiers

1. General Appearance

mottled
nodular
brecciated
fragmented
fractured
laminar
massive

2. Grain Size

grains larger than 2 mm
very coarse (1.0-2 mm)
coarse (0.5-1 mm)
medium (0.25-0.5 mm)
fine (0.125-0.25 mm)
very fine (0.0625-0.125 mm)
microcrystalline, cryptocrystalline

3. Porosity

intercrystalline
vuggy
fracture
leached
intra-skeletal

4. Replacement or Alteration

anhydritic
pyritic
stylolitic
cherty
white tertiary dolomite

5. Form of tertiary white dolomite

laminar or banded
pseudo-brecciated
biogenic
birdseye
polka-dot
vug lining

DIAGENESIS

Diagenesis is the process involving the chemical and physical changes in sediment after deposition that converts it to consolidated rock. The controlling factors in early diagenesis as pointed out by Ginsburg (1957) and Friedman (1964) are the temperature, pH, Eh and salinity of the water, the variety of calcareous sediment accumulating (initially composed of aragonite and/or low magnesium calcite), the amount of organic material available, and biotic action. These factors control in part the processes which lead to consolidation. The consolidation of calcareous sediments is accomplished by compaction, cementation, pore filling, neomorphism (recrystallization or inversion) and replacement, in particular dolomitization.

The subject of diagenesis is only briefly discussed in this report and is not intended to be a complete documentation of the complexities encountered. Much of the original textures of the sediment have been destroyed through dolomitization, however it can be reconstructed in many instances.

Organic Processes

Studies of recent carbonate sediment indicate that organisms play a significant part in the early stages of diagenesis (Ginsburg, 1957). Movement of soft bodies organisms through sediment destroy lamination, producing disturbed zones which may be preserved as mottles or borings. Bacterial activity has an even greater role, in as much as they can control the pH and Eh of sea water. Both the release of carbon dioxide and ammonium bicarbonate by bacterial decay promotes calcium carbonate precipitation. Other processes of variable importance are particle size reduction, aggregation processes such as the formation of lumps and pellets, and the breakdown and synthesis of organic and inorganic compounds (Ginsburg, 1957).

It is not unreasonable to expect these processes to have occurred in the past

much the same as they occur today. There is no direct evidence to substantiate biotic activity within the reef, however, the lack of recognition is not taken to indicate the absence of such processes. Certain rocks have textures, lack of stratification and faint mottling, which suggest the activity of burrowers.

Cementation

The cement occurs as a clear crystalline calcite (spar cement) which may have formed in two ways, either by direct precipitation into a cavity and/or by neomorphism of previous calcite or aragonite. Both processes are of importance in the consolidation of the reef limestones.

Two forms of calcite cement formed by direct precipitation have been recognized. They include (a) a fringing calcite cement and (b) a clear granular cement.

a) The fringing calcite cement (Plate 3, Figure 2) consists of a narrow rim of radially orientated "fibrous" calcite that line original voids or cavities. It is commonly associated with laminoid fenestral fabrics (Tebbutt *et al.*, 1965). Where it can be recognized in hand specimen (uncommon) it occurs as a white calcite lining. This is the first cement to be deposited and is believed to be an early diagenetic event. It may be formed in sediments that are sub-aerially exposed as on tidal flats, or by bacterial precipitation from entrapped sea water during early burial.

b) Clear granular calcite cement (Plate 3, Figure 2) occurs as equant unorientated grains that infill or partially infill the centers of cavities occupied by the fringing calcite cement. It is the more abundant form of calcite cement.

Recrystallization

In a few instances, the spar cement is thought to represent recrystallization from micrite. This is suggested by: (a) extension of spar as void fillings (Plate 2, Figure 4), (b) irregular and diffuse contacts of pelmicrite with pelisparite layers, and (c) grains "floating" in coarse spar. Some pellets and lumps have also been partially recrystallized (Plate 2, Figure 2). For a complete discussion of the criteria used to

distinguish the various types of calcite the reader is referred to Bathurst (1958), Orme and Brown (1963), and Folk (1965).

Compaction

Compaction is the decrease in bulk volume of sediment resulting from compressive stresses induced by the overlying weight of sediment. In carbonate sediment, the degree of compaction depends primarily upon the time and degree of lithification. The consolidation of most carbonate rocks was apparently accomplished early. This conclusion is substantiated by the lack of evidence supporting compaction.

Pray (1960) has documented evidence to support the lack of compaction in carbonate rocks. Pray's observations are supported in this study. The evidence includes (a) the preservation of algal stromatolite structures in relatively undisturbed growth position. (b) An absence of squashed or flattened pellets and lumps. (c) The preservation of delicate fossils without any signs of crushing.

Stylolitization

The stylolites are variable in both size and shape, ranging from microscopic to macroscopic. Associated with the stylolite seams are accumulations of dark brown or black insoluble residues of probable bituminous-organic origin. Pyrite and dolomite rhombs occur in close proximity to the seams (limestones).

Stylolite abundance varies with lithologic character. Stylolites, especially microstylolites are much more abundant in the dark, bituminous fine grained skeletal or non-skeletal dolomites and limestones, than in the clean fossiliferous or pelletal carbonates. The presence of bituminous or organic material apparently favours the formation of stylolites. The association of stylolite abundance with carbonate facies has been noted in other reef studies such as Goose River (Jenik, 1965) and Carson Creek (Leavitt, 1966).

The stylolites are most likely of late diagenetic origin, and may have more

than one mode of formation, although the majority probably formed through processes involving pressure and solution. The reader is referred to Stockdale (1922), Shaub (1939) and Dunnington (1954) for a more complete review on the formation of stylolite.

Dolomitization

Relict limestone textures and structures indicate that all the dolomite is of secondary origin. At least two stages of dolomitization are involved: an early stage of dolomitization, the formation of which may have involved the refluxing of magnesium rich brines, and a late stage cavity filling precipitate and replacement dolomite of probable hydrothermal origin.

Early Stage Dolomite

The majority of the dolomite encountered in the reef is thought to represent an early stage of dolomitization. The process of dolomitization is not understood, and one can only reflect that perhaps a process similar to that recorded by Deffeyes et al., (1965) at Bonaire was responsible. Such a process could account for the remnant limestone beds in the upper portions of the reefs. However, it does not explain why some of the neighbouring reefs are limestone throughout.

Examination of the dolomitic limestones and calcareous dolomites in the upper portions of the reef complex aid in understanding the dolomite textures and structures encountered in the lower completely dolomitized portions. The degree of confidence in interpreting these dolomite textures is also enhanced by this examination.

The dolomite occurs in two distinct forms within the limestone beds of the upper Rainbow Member, as (a) replacement of allochems, and (b) as a calcite cement replacement.

(c) Replacement of allochems - Within the biogenic pelleted muds and algal lump limestones, the dolomite first appears as isolated or clustered rhombs. The single dolomite crystals are well formed, commonly zoned having a dark central core and vary in size from 0.05 mm to 0.3 mm in diameter. Where dolomitization has been more extensive, mutual interference of crystals result in dense mosaics containing

anhedral to subhedral crystals. Sucrosic dolomites with good intercrystalline porosity develop from partially dolomitized sediments, from which the remaining calcite has been dissolved by later solutions. Sucrosic textures have formed from both micrite and pelmicrite.

The crystal size appears to be a direct function of the original crystallinity of the sediment (with minor modification). The finer the original sediment the finer the resulting mosaic. This is not always the case, as micritic sediments have been dolomitized to medium crystalline dolomite. The consistency of crystallinity is usually a better indication of the original sediment character. It can be used to indicate the original degree of sorting. A uniform or consistent dolomite mosaic reflect well-sorted sediments, while mixtures of coarse, medium and fine dolomite crystals indicate originally poorly sorted sediments.

Outlines of pellets and lumps are sometimes preserved as inclusions within single or multiple dolomite crystals (Plate 2, Figure 6). Care must be taken to avoid misinterpreting zoned dolomite crystals as representing a pellet fabric. On the other hand, the organic constituents are reproduced by crystals tending to have either a finer or coarser crystallinity than the surrounding matrix. Birdseye textures tend to be preserved as lighter coloured elongate patches or vugs (Plate 3, Figure 3).

(b) Replacement of cement - There appears to be a preferential tendency to replace both organic and inorganic allochems prior to the spar cement found in cavities (Plate 2, Figure 8). In a few instances dolomite was found selectively replacing the spar cement, both fringing and clear granular varieties. Both the grain shape and size are retained in this replacement process (Plate 3, Figure 2). Where both the spar cement in cavities and the surrounding framework and matrix material are dolomitized, the replaced spar cement takes on a lighter colour (Plate 3, Figure 3).

A white dolomite cement is apparent in certain horizons and is most commonly

associated with non-dolomitized fossil detritus, especially amphiporoids. This white dolomite may or may not be related to the white dolomite discussed below.

Late Stage Dolomite

Throughout much of northwestern Alberta and parts of northeast British Columbia a distinctive white coarsely crystalline dolomite is found within the carbonates (especially porous reef or reef-like facies) of the Middle Devonian. They occur in the Slave Point Formation of northeast British Columbia (Gray and Kassube, 1963), Presqu'ile Formation of northeast Alberta (Law, 1955) and Keg River Formation (this report). At Pine Point, similar dolomites occur along with sphalerite and galena in the Presqu'ile Formation. This has been interpreted to be hydrothermal, with the temperature of formation (oxygen isotope studies) calculated to be between 50°C and 100°C (Singh, 1967). Although the relationship of the white dolomite in these different localities has not been established, their similarity in form suggests a common origin.

In the B Pool reef the white dolomite is present in the upper Rainbow Member, and is most prevalent in zones associated with biogenic carbonates. The white dolomite occurs most commonly as vug linings, stringers and isolated blebs, commonly orientated parallel to the bedding. Brecciated or marbled textures are prevalent where the white dolomite occurs in large amounts. In these zones, core is commonly lost suggesting the presence of large vugs or caverns. The Presqu'ile Formation at Pine Point has caverns with associated white dolomite (Beales and Jackson, 1966), and in all probability the Keg River Formation is similar.

Descriptive terminology can be coined for the various ways in which the white dolomite occurs. The terms are not intended to suggest different types of dolomite (although they may not have a common mode or origin). Griffith (1964) gives six descriptive names to describe the distribution of the white dolomite. However, new

terminology is introduced to describe the distribution of the white dolomite in the Keg River Formation. The point of difference between the two classifications result from the identification of particular textures such as skeletal and birdseye textures. The writer feels that if skeletal material can be identified as having been replaced by white dolomite, it should be so classified. In addition, the difference between the two terms "clotted and nebulous textures" is not readily apparent and therefore are not used. The terms "banded and pseudo-brecciated" are retained.

The white dolomite is similar in all forms encountered and is typically very coarsely crystalline. Crystals as large as 2 mm are common, but they normally average 0.5 to 1 mm in diameter. These crystals are usually curved (resulting in waving or strained extinctions) and euhedral.

Laminar or Banded Texture (Plate 4, Figure 1)

This texture is represented by horizontal, parallel to subparallel bands of white dolomite alternating with remnant medium to dark brown dolomite. The white dolomite bands vary from less than 1 mm up to several centimeters in thickness. The thinner bands are commonly crenulated. Vugular or pinpoint porosity is normally associated with the centers of the bands. The percentage of white dolomite is variable, but is generally less than 50%. This form of dolomite replacement grades into the birdseye variety discussed below. Fine stringers less than 0.5 mm thick, along with thicker bands and elongate lenses of white dolomite form an intermediate stage to the development of a birdseye texture (Plate 4, Figure 5). Occasionally the bands are not as distinctive, and take on a marbled appearance (Plate 4, Figure 8).

Microscopic examination reveals that the darker dolomite is composed of fine to medium anhedral crystals. These crystals are uniformly pigmented.

The distribution of the white dolomite in the finer bands is very similar to the distribution of the spar cement in laminoid fenestrate limestones encountered in the

upper horizons. This suggests that this variety of white dolomite has formed by the replacement of spar cement. However, the white dolomite is frequently of thicker aspect reflecting some replacement of matrix material. Horizontal elongate gaps (formed by leaching or incomplete infilling of spar cement in laminoid fenestral carbonates) formed prior to the introduction of white dolomite could also be responsible for this particular distribution. The porosity found in the centres of the bands may have resulted from incomplete dolomitization and later removal of the calcite core, or by incomplete infilling of pre-existing voids. The controlling factor or factors for thicker (greater than 1 cm) and more abundant white dolomite distribution is not known. Interbedded anhydrite (later removed by solution) and carbonate sediment might have been responsible.

In some instances stromatoporoid fragments can be recognized as having been replaced by white dolomite (Plate 4, Figure 9). The white dolomite occurs as regularly spaced bands, commonly spaced every 0.5 cm. These bands are often concentric and almost always develop into vugs lined by white dolomite. In many instances, it is difficult to distinguish between stromatoporoids and algal laminated sediments, particularly when the structure is continuous across the entire core.

Pseudo-breccia Texture

Typically, the texture is represented by angular "fragments" of medium to dark brown dolomite "cemented" by white coarsely crystalline white dolomite (white dolomite replacement breccia). The fragments tend to be less than 4 cm in diameter and are composed of fine to medium dolomite crystals (similar to that previously described). Depending upon the amount of white dolomite present, various varieties can be distinguished. When the white dolomite occurs in minor amounts, it has more of a vein like distribution, which transforms into a white dolomite replacement breccia with increasing white dolomite content. The content can increase to such proportions

that scarcely any dark dolomite remains. Porosity is generally poor to non-existent in rocks having this variety of white dolomite.

The reason for this distribution is uncertain. Primary dolomite breccias are as common, and are frequently cemented by anhydrite. Leaching and/or replacement of the anhydrite by white dolomite could explain some of the occurrences.

Biogenic Texture

This includes all the non-laminar forms of white dolomite in which skeletal material can be recognized as having been replaced by white dolomite. The fossil forms recognized include solitary corals, gastropods and shell fragments. In this form, the white dolomite seldom exceeds 10 per cent and generally represents less than 5 per cent, depending upon the skeletal material present. Care must be taken not to become influenced too much by the recognition of skeletal fragments, and start identifying all irregular and round shaped isolated "inclusions" of white dolomite as skeletal.

Polka-dot Texture (Plate 4, Figure 4)

Round blebs of white dolomite less than 5 mm in diameter are found "floating" in a matrix of light to medium brown medium crystalline dolomite. The "inclusions" have sharply defined boundaries, and generally represent less than 10 per cent of the rock. The shape and distribution of the white dolomite is non-diagnostic.

The texture could result from the replacement of skeletal fragments. In this case, the occurrence and distribution of biogenic material would control the amount and size of the white dolomite blebs. The texture could also reflect poorly preserved "birdseyes".

Birdseye Texture (Plate 4, Figure 6)

White dolomite occurs in the same shape, form and size as "birdseyes". The

inclusions are isolated and practically always less than 4 mm in size. They can be mistaken for the polka-dot texture described above. The texture is formed by the direct replacement of void filling spar cement.

Vugular Texture (Plate 4, Figure 7)

White dolomite occurs as a thin lining surrounding irregular shaped vugs. The vugs are variable in size, ranging from less than 5 mm to more than 5 cm. The vugs may have only a thin lining, or may be more completely infilled by white dolomite. In some instances the host dolomite becomes darker near the edges of the replacing white dolomite (Plate 4, Figure 10). The darkening of colour may result through a redistribution of carbonaceous material as suggested by Griffith (1964), or may be the entrapment of an early hydrocarbon residue (Gray and Kassube, 1963).

This form of white dolomite can grade into various of the above mentioned textures, but invariably is related to zones of abundant white dolomite. Lost core and poor recovery is also typical of these zones, suggesting a vuggy dolomite. The distribution of the white dolomite in these more porous zones is thought to be similar if not identical in appearance to that encountered at Pine Point in the Presqu'ile Formation (Plate 4, Figure 11). Beales and Jackson (1966) have interpreted this "lattice work structure" to be the result of evaporite solution and brecciation. A similar process could conceivably be possible for the formation of these structures in the Keg River Formation.

Non Carbonate Minerals

Anhydrite, chert, and pyrite are the principal non carbonate diagenetic minerals encountered in the Keg River Formation. Of these, anhydrite is the most abundant and significant accessory mineral.

Sphalerite, galena, and fluorite are rarely observed. Although these three minerals are known by only a few isolated occurrences, they suggest the passage of "hydrothermal" solutions through the reef.

Anhydrite: Three forms of anhydrite occur within the reef complex, namely, nodular masses, clear crystals, and replacement veinlets and lenses.

Nodular masses - This form is represented by irregular tuberous shaped masses or nodules of anhydrite less than two inches in diameter, surrounded and separated by dolomite. The anhydrite is frequently white or light brown depending on the impurity content. The nodules are composed of tightly interlocking needle-like crystals less than 300 microns long. The boundary between the nodules and surrounding carbonate sediment is sharp, with bedding planes occasionally draped around the nodule.

The anhydrite is similar to that encountered in the overlying Muskeg Formation, and for this reason is considered to be of primary origin. It occurs only in the upper 80 feet of the Rainbow Member and is associated with sediments interpreted to be deposited in the "inter-tidal" facies.

Clear crystals - Clusters of clear tabular or rectangular crystals of anhydrite are found filling pre-existing voids, especially vugs and fractures. These crystals are commonly twinned and are generally less than 2 mm in size.

Replacement veinlets and lenses - Replacement anhydrite is the most abundant form of anhydrite within the reef complex. The majority occurs as irregular or rounded masses, veinlets and isolated crystals with no apparent control for its occurrence. It replaces both host dolomite and replacing white dolomite. Occasionally the replacement has been selective, with both spar cement and biogenic material replaced preferentially to the host rock.

Anhydrite replacement is considered to be a late diagenetic event as indicated by the replacement of both spar cement and white dolomite. However, this does not mean that some replacement could not have taken place during early diagenesis.

Chert: Chert is rare and in the Rainbow Member it is present only as microscopic patches replacing skeletal grains. Chert becomes more abundant in the platform beds, where it occurs as lenses or nodules.

Pyrite: Pyrite is present in minor quantities in most rock types. It occurs in appreciable amounts in the darker argillaceous and bituminous rocks and in conjunction with stylolites and fractures.

Miscellaneous

Pyrobitumen: A black pyrobitumen-like substance is found staining and infilling fractures, vugs, and intercrystalline porosity. This material is restricted to a 100 foot zone, normally above the oil-water interface within the upper Rainbow Member. In this zone, porosity is appreciably reduced by this material, especially in the Banff Mobil Rainbow West 13-2 and A3-10 wells. Hriskevitch (1966, p. 249) has recognized similar material in the A Pool reef and states that it has been identified, at one location as carbon.

Grey Dolomite: Dark grey dolomite "inclusions" often with stylolite solution and fracture, occur in the lower Rainbow Member of the Banff Mobil Rainbow West 16-15 well and in the upper Rainbow Member in the Banff Mobil Rainbow West 10-10 well. For the most part these inclusions are variable in size, irregularly shaped and have a haphazard distribution. However, they are often elongate, concentrated in zones, have sharp contacts with the host dolomite, and are less than 5 cm in length. The inclusions are highly pyritic and carbonaceous. The origin of these inclusions is problematical. They may represent dolomitized argillaceous limestone or calcareous shale "clasts" formed by the ripping up of semi-consolidated lime muds and shale, and deposited in quieter waters. Some have probably formed in conjunction with stylolitization.

Fractures and Secondary Openings

Nearly all the carbonates in the Rainbow Member have been affected to various extent, by selective void forming dissolution. Skeletal grains are particularly susceptible to solution, with either the centre or whole fossil dissolved away. Some of the leached organic porosity could conceivably be related to the dolomitization process. Similar leaching of skeletal grains has been regarded by Murray (1960) and Weyl (1960) to be part of the dolomitization process. Recent examples of this phenomenon have been reported from the Persian Gulf (Illing *et al.*, 1965) and from Bonaire (Deffeyes *et al.*, 1965). Porosity in the upper Rainbow Member is commonly connected with the solution of void-filling spar cement (laminoid fenestral carbonates). Some vugular porosity may also result from the solution of anhydrite. Inter-crystalline porosity is formed in some partially dolomitized carbonates by the solution of the remaining calcite.

Fractures are common, and for some unknown reason become abundant in particular zones. They are random to vertically orientated and probably represent several periods of formation. Minute vertical cracks (normal to the bedding) present in some of the laminoid fenestral carbonates (Place 5, Figure 12), are interpreted to represent desiccation or mud cracks. In other instances, tectonic activity may be responsible for some of the fractures. Porosity and crystallinity (in the dolomites) commonly increase at the margins of the fractures indicating recrystallization and solution. The porosity is usually patchy and poorly developed. Cementation by anhydrite is common along the fractures and related porosity.

Diagenetic Sequence of Events

An inferred time relationship for some of the diagenetic features in approximate order of occurrence are (1) cementation, fibrous followed by equant calcite cement; (2) dolomitization; (3) selective leaching of limestones, dolomites and anhydrite; (4) white dolomite replacement; (5) anhydrite replacing dolomite and infilling voids;

(6) Fracturing, stylolitization, silicification and further anhydritization. More detailed work on the inter-relations of the various parameters is needed before any definite conclusions can be reached.

PALEONTOLOGY

Modern organisms reflect the environment in which they live. Similarly, fossil organisms can be used to reconstruct ancient environments. Unfortunately, the fossil record has usually been altered by the degree of preservation (removal by scavengers, decay, bacteria or destroyed by leaching, recrystallization and dolomitization) and transportation (fossils occurring in environments other than ones in which they lived).

In this study, the environmental significance of the various faunas is based on their association with other faunas, sediment types and recognition of their mode of growth. The recognition of fossils in their original growth position is seldom possible owing to the limited view provided by cores, and the obliteration of relationships through dolomitization. Wherever possible criteria suggestive of in situ accumulation were used (Nelson et al., 1962). Fossil textures have been destroyed by both dolomitization and leaching, creating difficulty in identification. It is common-place to find vague impressions of fossils without being able to identify the forms except in the most general manner.

A general distribution of organisms throughout the reef complex is given for the upper Rainbow Member (see Figure 14), but has not been attempted for the lower Rainbow Member. With only two wells penetrating the lower reef member, it was not felt that a meaningful analysis of fossil assemblages could be given. Nevertheless, the distribution is thought to be similar to that proposed for the Redwater reef (Klovan, 1964).

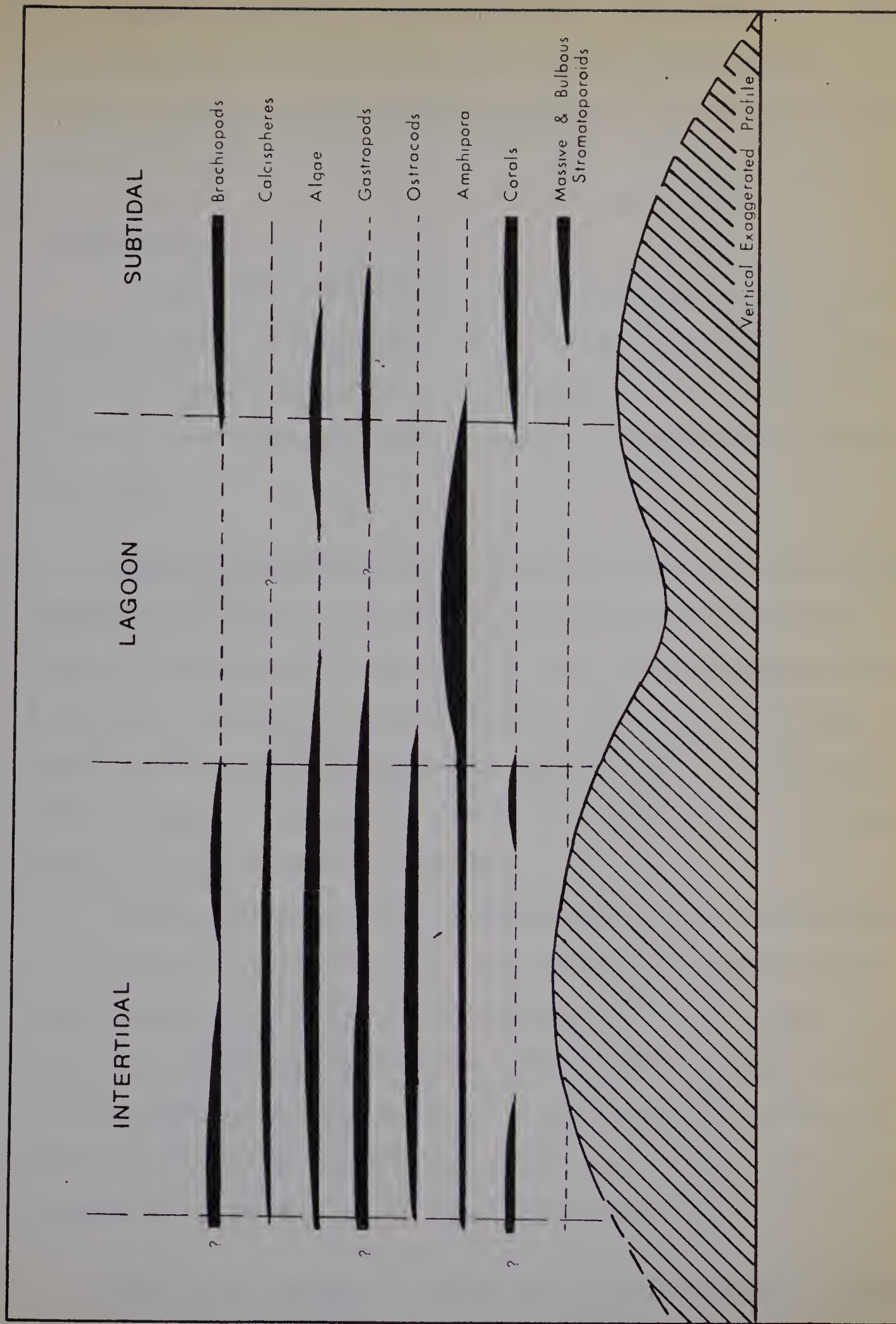


Figure 14. Generalized Distribution of Organisms in the Upper Rainbow Beach

There is a sharp contrast in the abundance of organic material, especially stromatoporoids and corals, between the upper and lower Rainbow Members. The paucity of organisms in the upper member is attributed to an unfavourable, possibly saline environment.

Stromatoporoids

In keeping with other reef studies, the stromatoporoids have been subdivided into four categories, namely, massive, tabular, bulbous, and dendroid. The dendroid varieties are the more abundant form of stromatoporoid in the upper Rainbow Member, while massive stromatoporoids, possibly of the family Clathrodictyidae, dominate the lower member.

Massive Stromatoporoids - Massive stromatoporoids include all dome-shaped or subspherical growth forms, whose widths approximate their vertical dimensions. These forms are characterized by the large sizes they attain. The preservation of microstructure is usually poor, and commonly represented only by leached "crust-like" plates. Massive stromatoporoids are significant framebuilders forming as much as 70 per cent of the rock in the organic reef facies of the lower Rainbow Member. They are noticeably lacking in the rocks of the upper reef member.

Massive stromatoporoids preferred shallow turbulent waters, and formed the wave resistant portion of the reef front. These conclusions are based on evidence similar to that presented by Klovan (1964) and Murray (1966). This includes: (a) the fact that massive stromatoporoids are often fragmented and overturned; (b) an association with fragmented remains of other organisms; (c) the presence of a coarse skeletal matrix; (d) an occasional association with oncolites; (e) the fact that massive stromatoporoids are best developed at the margins of the reef complex.

Tabular Stromatoporoids - Tabular stromatoporoids are "pancake" or plate-like

in form. They can vary in thickness from 2 mm to 10 cm (Klovan, 1964), although the maximum size recognized in the Keg River Formation was only 6 cm. Tabular stromatoporoids are absent in the upper Rainbow Member, and occurs only in minor quantities in the lower Rainbow and Keg River Members. They are normally found flat-lying, together with crinoids, brachiopods and fragmentary corals in dark micritic sediments.

The limited data available suggests that tabular stromatoporoids preferred the quiet muddy environments of the fore-reef and basin. Similar environments are suggested by other reef studies (Klovan, 1964).

Bulbous Stromatoporoids - This growth form includes all spherical "cabbage-like" stromatoporoids. Most forms are well rounded, show no means of attachment, and are less than 8 cm in diameter. They are encountered only in minor amounts in both upper and lower Rainbow Members. In the lower member they are associated with oncolites, rugose, and tabulate corals, and massive stromatoporoids of the organic reef facies.

Bulbous stromatoporoids appear to prefer environments similar to that enjoyed by massive stromatoporoids. However, the relative absence of massive stromatoporoids in zones containing bulbous forms may reflect a preference for a somewhat different environment, possibly deeper and less turbulent as suggested by Murray (1966). Their presence in the upper reef member may reflect a higher tolerance to salinity than the massive varieties.

Dendroid Stromatoporoids - This group includes all ramose or digitate growth forms. The forms belonging to the genus Amphipora and to the genus Stachyodes are distinguished for the purpose of this study.

(a) Amphipora - Amphipora is a problematical genus considered to be a dendroid stromatoporoid by many paleontologists (Family Incertae sedis by Lecompte 1956, and Family Idiostromatidae by Galloway 1957). Amphipora is the most common

stromatoporoid found in the upper Rainbow Member. No Amphipora were encountered in the lower reef member, but their absence is interpreted to be due to a lack of control rather than an actual absence. A few scattered Amphipora also occur in the Lower Keg River Member.

Amphipora is generally 2 to 5 mm in diameter, and stalks up to 4 cm long have been observed. They are most commonly found flat-lying with their long axes parallel to the stratification. No branching types were seen, and their mode of growth is uncertain. Hollow cylindrical structures (Plate 6, Figure 1) have been interpreted to represent leached amphiporoid stalks. This is suggested by the size, shape, and form of the "tubules", and the occasional recognition of Amphipora associated with these forms.

In the limestone beds of the Rainbow Member, small amounts of Amphipora occur in pelletal or micritic sediments. The majority are present as leached forms in what has been interpreted as representing a lagoonal environment. For this reason, Amphipora is considered to represent a quiet water form that enjoyed the higher saline restricted (unoxxygenated) conditions of the lagoon or back-reef. Similar habitats for Amphipora have been suggested by other reef studies, including Redwater (Klovan, 1964), Judy Creek (Murray, 1966), and Goose River (Jenik, 1965).

(b) Stachyodes - Stachyodes is mainly found as stubby cylindrical branches up to 4 cm long. It never occurs in great abundance in either the upper or lower Rainbow Members. In the upper reef member it is associated with the intertidal sediments, while in the lower member it is found with corals and tabular stromatoporoids of the reef to fore-reef facies. From its association with other organisms, it can be concluded that Stachyodes preferred moderately turbulent conditions, similar to that favored by corals and massive stromatoporoids. The appearance of Stachyodes with intertidal sediments does not indicate in situ accumulation, but represents fragments which have been washed up on tidal flats.

Corals

Corals are abundant in the reefal facies of the lower Rainbow Member and, next to the stromatoporoids, are the most important contributors to the bulk of the organic reef. They also occur sporadically in the upper Rainbow and Lower Keg River Members, generally associated with other organic debris including brachiopods and gastropods.

Thamnopora (includes the forms Cladopora and Coenites) is found throughout the Keg River Formation and generally occurs as colonies. Most specimens seen were fragmented, although stalks up to 6 mm in diameter were observed. One zone in the lower reef member is characterized by "Favosites limitaris". They appear to be in a deeper more fore-reef position than the massive stromatoporoids. Alveolites is not abundant, its absence is attributed to a lack of preservation. In the one instance in which it has been identified it occurred together with Thamnopora.

Syringopora is rarely observed in the Lower Keg River Member. Klován (1964) suggests that it is tolerant of muddy conditions and lived in a quiet to moderately turbulent environment.

Favosites has been encountered in a few isolated instances in both the Rainbow and Lower Keg River Members. It has not been found in growth position.

The solitary rugose corals Digonophyllum and Disphyllum occur together and are present only in the lower reef member. They are associated with massive stromatoporoids, and tabulate and septate corals. Dendrostella occurs as individual stalks but was not encountered in growth position. The frequency of occurrence of these forms and their association with stromatoporoids suggests a preferred environment, probably similar to that enjoyed by massive stromatoporoids.

Brachiopods

Brachiopods are ubiquitous in most reef rocks but are never very abundant.

They are one of the most poorly preserved fossils in the Rainbow Member, generally being leached away forming organic porosity. In the upper Rainbow Member brachiopod shells and fragments are most commonly found with the intertidal sediments. Spiriferids appear to be the most common type present. One Stringocephalus has been identified (Plate 1, Figure 7). In the lower reef member brachiopods are associated with the reef to fore-reef sediments.

Lingula occurs in the upper argillaceous unit of the platform. Present day Lingula is found only on muddy bottoms in shallow water, and presumably enjoyed similar conditions in the past.

Gastropods

Gastropods occur in most of the rock types as scattered individuals. They are especially characteristic of the intertidal sediments of the upper reef member, where their identity is preserved as internal molds or steinkerns. Several beds consisting almost entirely of gastropods (Murchisonia?) have been encountered in the upper Rainbow Member, and have been interpreted to represent a beach deposit. In the lower reef member, they are commonly found together with reef-building organisms.

Modern gastropods can tolerate a wide range of environmental conditions and it is most likely that their distribution and tolerance to environmental conditions was the same in the past as in the present.

Pelecypods

Pelecypods appear to be relatively scarce. Not one genus has been recognized from the entire reef complex.

Crinoids

Crinoid ossicles are abundant in the platform rocks and basal portion of the Rainbow Member. They are absent in the upper reef sediments. The crinoids normally

are associated with dark bituminous carbonates, and occasionally occur in minor amounts with stromatoporoids and corals of the reef facies.

The limited evidence available suggest that the crinoids preferred quiet water conditions, possibly in the fore-reef or basinal environments. The association with stromatoporoids suggest that they might also have lived on the reef proper, in sheltered environments.

Ostracods

Ostracod shells were found only in the upper Rainbow Member where they occur in intertidal sediments. Their absence in other facies might be attributed to poor preservation.

Bryozoans

Bryozoan fragments are rare, and have been identified (Cheilotrypa?) in only one location from the Lower Keg River Member (Plate 1, Figure 4). However, bryozoans have been identified in the Rainbow Member from other reefs in the Zama Lake region (oral comm. D.A. Pounder, Chevron Standard Limited).

Tentaculites

These have been found throughout the Lower Keg River Member and are reported from the middle argillaceous unit of the Upper Keg River Member (Hriskevitch, 1966).

Conodonts

No conodonts were observed, but they have been recognized from the Lower Keg River Member (oral comm. D.A. Pounder).

Astraeospongia

Sponge spicules, tentatively identified as Astraeospongia were encountered in several bands within the platform beds. They occurred in the Banff Mobil Rainbow

West 16-15 well in the interval 6595 to 6615. The great majority of modern sponges inhabit shallow seas, and in all probability did so in the past.

Calcispheres

Calcispheres form a minor but conspicuous component of the rocks of the upper Rainbow Member. Unfortunately, they are only preserved in the limestones.

The exact origin of these spheroidal bodies is not known, although they have been thought to represent algal spore cases or possibly some sort of free-floating organism. In other reef studies such as Redwater, Carson Creek, and Goose River, the calcispheres have been associated primarily with the lime muds of the back reef or lagoonal facies. This would suggest quiet shallow water surroundings. In the Rainbow Member, the calcispheres are found together with pellet lime muds and laminoid fenestral carbonates. These sediments would tend to indicate an inter-tidal environment for the accumulation of calcispheres. Their presence could reflect algal influence either directly as algal spore cases, or indirectly indicating their entrapment along with other sediment particles by mucilaginous algal sheaths. Their occurrence in various sediment types can be explained by their susceptibility to transportation, as well as preservation phenomenon.

Algae

Studies of modern reefs indicate the important influence algae have on carbonate deposition. Recent algae are important contributors to the formation of lime mud and skeletal sands, and play a significant part in the cementation of loose skeletal constituents. Blue-green algae are also well known for their role in entrapping sediments on their mucilaginous sheaths (modern oncolites and stromatolites). Unfortunately, algae leave little record of their presence in the rocks. For this reason their role in ancient reefs is difficult to assess. This study is no exception, with only minor amounts of algal material recognized in the lower reef member, and little direct evidence suggesting

algal activity in the upper member.

Three types of algal deposits are recognized, and a fourth type referred to as laminoid fenestral carbonate (laminite of Klován, 1964) suggest an algal influence.

Oncolites - Oncolites are locally abundant in the lower Rainbow Member, associated with stromatoporoid fragments and various other skeletal debris. They usually have a round or oblate shape, and are less than 3 cm in diameter. These forms contribute only a minute amount to the bulk of the reef complex. In the upper reef member, skeletal debris is frequently encrusted by "algae". The algal coating can only be inferred as the textures have been destroyed by dolomitization.

Ginsburg (1955) states that modern oncolites form in water one to six feet deep, while Logg et al., (1964) indicate that continuous motion is necessary for the development of spherical shapes. The association of oncolites with fragmented skeletal material indicate similar conditions were responsible for their formation in the reef complex. Hence, it can be concluded that oncolites suggest shallow, moderately turbulent marine waters.

Dasycladaceae - Stems and branches of Dasycladacean algae are preserved in laminated limestones of the upper reef member. They occur in horizontal bands parallel to the bedding. Nowhere do they occur in great abundance.

Modern Dasycladacean algae normally occur at depths from low tide to 10 meters, with the greatest development taking place just a few meters below low tide level (Pia, 1920). They have also been reported to occur on tidal flats. Presumably, these algae preferred a similar environment in the past.

Stromatolites - Some of the sediment in the upper portion of the Rainbow Member is interpreted as having been deposited by algal mats. The influence of algae on deposition is suggested by the similarity of the sediment with recent algal rock fabrics.

The sediment is characterized by well developed laminar structures consisting of alternating dark bituminous (algal in origin) laminae with lighter coloured laminae. In part they resemble the closely spaced linked hemispheres (LLH-C) of Logan et al., (1964).

Recent algal laminated sediments are accumulating in the intertidal and intermittent sub-aerial mud flats of Florida and the Bahamas (Black, 1933; Ginsburg et al., 1954). The mechanism of sediment binding and lamination have been discussed by both Black (1933), and Ginsburg (1960). Black showed that the lamination may be produced in the following three ways:

- "1) Rhythmic variation in quantity of filaments of one species or group of species, with relation to the quantity of sediment.
- 2) Alternation of two species or of two groups of species.
- 3) Sediment laminations in mineral particles enclosed between filaments."

Ginsburg (1960) believes that alternation of sedimentation with the growth of a surface algal mat is the chief cause of lamination. The sediments of the Rainbow Member are thought to have formed and developed under similar conditions.

ANALYSIS OF THE MUSKEG FORMATION

In the Rainbow Field area the Muskeg Formation consists of two member (see Figure 3); an upper unnamed member of interbedded anhydrite, limestone, dolomite and shale, and a lower or Black Creek Member consisting almost entirely of salt (halite). The Muskeg Formation varies in thickness from 150 feet over the reefs to more than 700 feet in the inter-reef area. As such, the Muskeg Formation infills the depressions and overlies the isolated Keg River reefs.

The observations of the Muskeg Formation, are based primarily on the core examination of the Banff Mobil Rainbow West 13-2 well. Unfortunately no Muskeg

section was available for examination in the stratigraphic interval equivalent to the upper Rainbow Member. The lower contact with the Black Creek Member was cored and examined in the Banff Mobil Rainbow West 9-24 well.

Upper Muskeg Member

The upper Muskeg Member consists largely of interbedded anhydrite and dolomite with minor amounts of limestone and shale. The contact with the Black Creek Member is sharp and represents a normal upward sequence of salt to anhydrite. The upper contact with the Sulphur Point Formation is abrupt and marks the disappearance of evaporitic beds.

The anhydrite occurs in various forms throughout the Muskeg Formation; more specifically, "chicken wire" or nodular, massive, and laminar. Massive and nodular anhydrite are the most common varieties with laminar anhydrite occurring infrequently and then predominantly in contorted bands. The chicken wire or nodular form (Plate 5, Figure 1), refers to irregular masses of white anhydrite commonly less than two inches in diameter, surrounded and separated by medium to dark grey brown impure anhydrite. The impurities consist of dolomite, pyrite, and organic material. The nodules are commonly orientated with their long axes parallel to the bedding. All forms of anhydrite exhibit a tightly interlocking fabric of needle-like crystals in which the individual crystals are preferentially orientated sub-parallel to parallel to the bedding. The anhydrite is commonly white, with impurities darkening the colour to medium or dark grey brown.

The dolomite is light to medium brown, banded or laminar, very finely crystalline and occurs in beds which seldom exceed 10 feet in thickness. The laminations result from the occurrence of bands of variable crystallinity and parallel streaks or partings of bituminous material. Many of the dolomites exhibit relict textures betraying their secondary nature. Pellets, lumps and fossil fragments may be recognized in thin section. Anhydrite crystals, nodules and cement are found in varying percentages

throughout most dolomite beds.

Two thin limestone beds are present in the Banff Mobil Rainbow West 13-2 well, but are probably more widespread in other areas. The limestones are pelletal and contain a few scattered skeletal grains.

Black Creek Member

The Black Creek Member is of variable thickness and consists essentially of massive salt (halite) with minor anhydrite interbeds or laminae. The salt member is presently restricted to the basinal areas, by virtue of either non deposition or removal by solution in the inter-basinal areas. A maximum thickness of 270 feet is encountered in the Banff Mobil Rainbow 9-24 well. This thickness probably represents the approximate thickness of salt attained throughout the Rainbow Sub-basin.

The base of the salt member is represented by a four foot anhydrite bed which immediately overlies the Keg River Formation (Upper Keg River Member). This anhydrite bed becomes increasingly calcareous as the top of the Keg River is approached. The anhydrite is medium to dark grey, consisting of irregular laminae 2 to 5 mm thick separated by layers of brown micrite and bituminous material less than 2 mm thick. The surfaces of the laminae are highly irregular and resemble load casts.

The halite is white, very coarsely crystalline (crystals up to 1 cm but commonly less than 6 mm) and clear, and contains little or no impurities. Grey anhydrite is present as irregular interbeds and laminae, which are seldom thicker than 5 cm and generally less than 1 cm. Tissue thin laminae of anhydrite are also prevalent. The anhydrite "interbeds" are found at intervals of roughly one to two feet, almost in cyclic fashion.

Recent Anhydrite

Most recent evaporites are forming on supratidal flats and in shallow lakes rather than in deep standing bodies of water. Studies of ancient evaporite deposits

and their comparison with recent deposits have led to interesting speculations. Kerr and Thompson (1963) conclude that the Permian evaporites (shelf sediments) of Texas and New Mexico were deposited in a tidal mud flat environment. Their conclusion is based on the similarity between recent gypsum deposits in the Laguna Madre of South Texas and these Permian evaporites. In the Laguna Madre, rosettes and bladed crystals of gypsum are found below the sediment surface and are formed by hypersaline ground waters derived from the overlying mud flat. They state that a "high density of gypsum crystals growing while excluding soft host sediments will result in densely packed layers of anhydrite nodules which may be mistaken for beds of anhydrite." Murray (1964) reaches similar conclusions. He suggests that nodular anhydrite is indicative of subaerial exposure of soft sediments. Sugden (1963) postulates that the shallowing of a large body of water similar to the Persian Gulf (mean depth only 25 meters) would lead to the deposition of evaporites.

Environment

The gross lithologic character of the Muskeg Formation indicates that it was deposited in a restricted environment under arid conditions. The development of a barrier reef (see Figure 5B) appears to have been responsible for the restriction.

Black Creek Member - The deposition of salt indicates highly restricted conditions and an abrupt change in basin environment. Under these highly saline conditions normal marine organisms could not survive. It is at this time that many of the reefs, especially those in the eastern areas were killed.

Upper Muskeg Member - The interbedded anhydrites and carbonates indicate a freshening of the waters. The environment of deposition alternated from arid restricted favouring anhydrite formation (precipitation of gypsum) to normal or near normal marine with attendant precipitation of carbonate muds. The carbonate sediment suggests periods of marine "incursion" resulting from sudden downwarping of the barrier, possibly with the development of cross-reef channels.

The presence of carbonate-anhydrite interbeds tends to indicate rapidly alternating conditions, and suggests shallow water conditions. It is much more difficult to achieve similar results with deeper waters, primarily due to the amounts of water required. Comparison with recent examples of anhydrite formation would suggest that part of the upper Muskeg Member (portion overlying the B Pool reef) was deposited in broad shallow flat-bottomed lagoons, which acted as huge evaporating pans.

ANALYSIS OF THE KEG RIVER FORMATION

The Keg River Formation consists of a lower widespread platform unit (Lower Keg River Member), an upper pinnacle reef complex (Rainbow Member) and associated inter-reef carbonates (Upper Keg River Member). Each member is discussed separately.

Analysis of the lower half of the reef complex is hampered by a lack of core control. Complete cores of the lower 500 feet are available only in two widely separated wells (Banff Mobil Rainbow West 16-15 and 3-3). Similarly, a lack of core control hinders the analysis of the Upper Keg River Member.

Rocks of the Platform

The platform can be correlated throughout most of northwest Alberta and to some extent into northeast British Columbia. Throughout most of this region it is entirely dolomite, while in the basinal regions, such as the Rainbow sub-basin, some limestone is preserved in the upper portions. The thickness of these upper limestone beds is variable, and is therefore unreliable for subdividing the platform. Subdivision of the platform is possible by virtue of a regional "argillaceous" interval, which occurs in the upper 50 feet. This subdivision corresponds to the upper and lower division of the Lower Keg River Member proposed by Hriskevitch (1966), but does not correspond to the limestone-dolomite boundary of the Rainbow Lake region.

In the Rainbow sub-basin, the thickness of the platform beds in the inter-reef positions is relatively constant (approximately 135 feet), whereas under the B Pool reef it varies in thickness from 120 feet (Banff Mobil Rainbow West 1-3 well) to 150 feet (Banff Mobil Rainbow West 10-10 well). The thickness appears to be controlled by structure.

Basal Dolomite

These beds form the basal unit of the Keg River Formation and rest with apparent conformity on the underlying Chinchaga Formation. The contact with the overlying limestone beds is sharp (verified only in the Banff Mobil Rainbow West 16-15 well). The average thickness under the B Pool reef is approximately 65 to 70 feet. However, it appears to be substantially thinner in several wells, notably Banff Mobil Rainbow West 1-3 well where it is approximately 30 feet thick (based on drill cuttings). Data derived from the Banff Mobil Rainbow West 16-15 well indicates that the basal dolomite is divisible into two lithologic units as follows:

- 1) An upper unit characterized by 33 feet of dense, non laminar, dark grey-brown, fine to medium crystalline dolomite, with abundant crinoid fragments and fine skeletal debris (less than 2 mm), and containing scattered fossil fragments (greater than 2 mm) including tabular stromatoporoids, favositid corals, and large crinoid ossicles; it is in part anhydritic, with white crystalline anhydrite occurring in veinlets or irregular blebs, and is occasionally stylolitic.
- 2) A lower dolomite unit, typically dark grey with brownish mottling, non-skeletal, very finely crystalline, massive, dense and containing irregular patches of black chert. Only 16 feet of this lithology has been cored, but this rock type is presumed to continue to the top of the Chinchaga Formation.

Platform Limestones

The upper limestone beds extend throughout the Rainbow sub-basin. The

contact with the overlying Rainbow Member is sharp and marks an abrupt change from dolomites to limestones.

The limestones of the platform are typically dark brown to dark grey brown, bituminous and micritic. They are non-laminar, dense and contain abundant stylolites. The majority of the beds contain finely disseminated skeletal debris (approximately 10% or more), which is primarily crinoidal. The fauna includes Thamnopora, brachiopods, pelecypods, corals and bryozoans; tentaculitids are locally abundant. Syringopora, Lingula, favositid corals and tabular stromatoporids are present in lesser quantities. Archaeospongia (?) spicules have been found in a few isolated bands.

In part the limestones are nodular to brecciated in appearance. The nodules consist of light to medium brown micritic limestone containing skeletal and non-skeletal grains, together with some spar cement. The matrix surrounding the "lithoclasts" consists largely of dark brown carbonaceous material, which has a laminated appearance due to the presence of abundant stylolitic seams. The nodules probably represent "boudinage type" lithoclasts which were formed by the compaction and stylolitization of biomicrites. In some instances, bands rather than nodules of similar biomicrite are separated by dark carbonaceous stylolitic seams.

Pyrite, chert, dolomite, and anhydrite are all present in minute amounts.

Environment

The environment of deposition probably varied from quiet stagnant to better oxygenated conditions which allowed a bottom community to develop. The basal dolomite represents a transitional period between the deposition of anhydrite to the establishment of a normal marine regime. The absence of fossils in the dark basal beds reflect a period of abnormal salinity and/or very muddy bottoms. The upper dolomite unit is similar to the overlying limestones which suggest somewhat more turbulent oxygenated conditions. The fossils Syringopora, Thamnopora, Lingula and tabular stromatoporoid all suggest a shallow water environment. The bituminous nature of the upper intervals suggest periods of reducing environment.

Inter-Reef Carbonates

The inter-reef carbonates correspond to the Upper Keg River Member. They have been subdivided into three units: a lower carbonate, a middle argillaceous units and an upper carbonate (Hriskevitch, 1966). In the immediate area of the B Pool reef the inter-reef carbonates vary in thickness from 150 to 175 feet, with each of the three units comprising roughly equal portions.

Lower carbonate unit

The unit is characterized by light to dark grey brown, fine to medium crystalline dolomite with abundant fine skeletal trash. Shell fragments, brachiopods, and gastropods are sparsely scattered throughout. Corals and stromatoporoids are locally abundant. Porosity, both inter-crystalline and vuggy, is generally poorly developed and results from the solution of organic remains. Microstylolites and anhydrite are common.

Middle argillaceous unit

This unit was not examined but, according to Hriskevitch (1966), it is composed of interbedded, slightly bituminous limestones and calcareous shales, and contains abundant tentaculites.

Upper carbonate unit

The upper unit consists of limestone, medium to dark grey, dense, bituminous, laminar to non-laminar and devoid of fauna. The majority of the beds are laminar, consisting of horizontal (occasionally contorted), micritic laminae separated by bituminous partings and stylolitic seams along which the rock tends to split rather easily. The laminae are seldom greater than 2 mm thick and are medium to dark grey brown, depending on the amount of bituminous material present. The non-laminar beds tend to be less bituminous, lighter coloured and pelletal. Within these beds are scattered unorientated to orientated black carbonaceous "wisps". Anhydrite seams and blebs occur in minor amounts throughout.

Environment

The inter-reef carbonates were deposited in continuously deepening water. The lower unit was deposited in shallow, quiet to moderately turbulent well oxygenated waters. This is indicated by the percentage and types of organism present, as well as the lack of bituminous material. Deposition of the upper unit took place in relatively deep quiet water (deposition below effective wave base) in an environment favourable for the precipitation of lime mud. Conditions were not favourable for organic growth indicating that restricted circulation may have prevailed. The laminated nature of the sediments suggest seasonal deposition, with the bituminous partings representing organic blooms. The non-laminated pelletal interbeds, suggest periods of reworking by burrowing organisms.

Facies Classification of the Rainbow Member

The top of the Rainbow Member is taken at the base of the main primary anhydrite (Muskeg Formation), which commonly coincides with the first appearance of stromatolitic beds. The presence of anhydrite is well displayed on gamma ray-density logs, thereby facilitating the regional mapping of the Keg River Formation. No erosion is apparent at the top of the B Pool reef in any of the cored wells. The contact represents a transition from predominately reefal carbonates to interbedded anhydrite and dolomite, suggesting continuous sedimentation without subaerial exposure. This is in contrast to the A Pool reef, where angular inclusions of reef-like material at the base of the Muskeg Formation suggests possible subaerial exposure prior to Muskeg sedimentation (Hriskevitch, 1966).

The Rainbow Member is divided into two informal stratigraphic units consisting of a lower organic reef complex (lower Rainbow Member) and an upper algal reef complex (upper Rainbow Member). The division between the two units marks an abrupt change in basin environment from normal marine well oxygenated waters

favouring organic reef growth to shallow "quiet" waters favouring growth of algal mats and the deposition of associated sediments. This division can only be made on the basis of core or sample examination (Electric logs show a marked increase in porosity for the lower unit). The boundary is gradational over a thickness of approximately 15 feet, and is marked by the sudden appearance of massive stromatoporoids and corals in the lower unit.

The rocks of both informal units are discussed individually and have been subdivided into facies and microfacies which are defined on the basis of their lithologic and paleontologic characteristics. These are portrayed on cross sections in Figure 15, 16, 17 and 18.

Organic Reef Complex (lower Rainbow Member)

The lower Rainbow Member attains its greatest thickness of 470 feet in the northwest, at the Banff Mobil Rainbow West 12-10 well. Facies control is lacking within this unit as only two wells penetrate the entire section. Fortunately, each well represents a somewhat dissimilar portion of the reef complex, and therefore allows a more meaningful interpretation to be applied. The facies recognized are summarized in Table 3, but this Table should, in no way, be interpreted as a representation of the entire spectrum of possible sediment varieties. More differentiation, would perhaps be possible with either greater control or more detailed work. The classification of the facies is somewhat similar to that proposed by Klován (1964).

Organic Reef Microfacies (a)

Lithology: Dolomite, light brown, containing more than 40 per cent skeletal components greater than 2 mm. Massive stromatoporoids predominate and their abundance, commonly one on top of the other, suggest a reef in growth position. Where the stromatoporoids are less numerous, they occur both as fragments and whole specimens, forming a bound fabric with entrapped sediment and fossil fragments. Associated with

TABLE 3

Facies Classification of the lower Rainbow Member (Organic Reef Complex)

FACIES	MICROFACIES	ENVIRONMENT
(A) REEF FACIES	(a) Organic reef	Wave resistant organic framework representing turbulent shallow water.
	(b) Stromatoporoid detritus	Fragmented organic reef deposited a short distance seaward or leeward of the organic reef. Excessive turbulence is the main controlling factor.
	(c) Coral detritus	Similar environment to microfacies (b)
(B) BACK-REEF FACIES	(d) Skeletal	Deposited in shallow, moderately turbulent water, leeward of the organic reef facies.
	Not distinguished in this study	
	Non-skeletal	Shallow, slightly restricted quiet water leeward of the organic reef facies
(C) FORE-REEF FACIES	(e) Reef-flank detrital	Reef derived rubble, (as well as indigenous fauna?) formed in moderately deep waters on the fore-reef slopes.
(D) BASINAL FACIES	(f) Crinoidal	Quiet, deeper water than microfacies (f) occurring in the outer fore-reef slopes and basin.

the massive stromatoporoids are rugose, tabulate, and septate corals as well as a few crinoids, brachiopods, and gastropods.

The matrix consists of a heterogeneous mixture of varying crystal sizes. Commonly two size ranges are apparent (bimodal), those less than 0.05 mm representing the mud fraction (?), and crystals with sizes greater than 0.4 mm representing ill-sorted unrecognizable skeletal (?) fragments.

Distribution: This facies is especially abundant in the Banff Mobil Rainbow West 16-15 well. The relationship of this facies with the western edge and interior of the complex is unknown. However, it is thought to be similar in distribution to the organic reef facies in the Redwater reef as outlined by Klován (1964).

Environment: The rocks of this facies represent the actual wave - resistant, organically constructed framework. This is interpreted as having developed in the zone of turbulence, where well aerated waters would favour their development.

Stromatoporoid Detritus Microfacies (b) (Plate 4, Figure 8)

Lithology: Dolomite, light brown generally with less than 40 per cent of the components greater than 2 mm in size. Massive stromatoporoids are still the most abundant forms, but usually are fragmented. Bulbous stromatoporoids, rugose, tabulate, and septate corals, and unrecognizable shell fragments are common. Brachiopods, dendroid stromatoporoids, oncolites and algal encrusted skeletal fragments are less abundant. This facies is characterized by the fragmented, transported appearance of the constituent grains.

The matrix material is similar in aspect to the organic reef microfacies, only is more abundant. In a few instances, inorganic constituents (lumps and pellets) appeared to be present. White dolomite cement (original spar cement?) binds some of the rocks.

Distribution: These rocks are intimately associated with the organic reef facies,

the boundary between the two being somewhat gradational.

Environment: Rocks comprising this facies consist of detritus derived from the organic reef. The intimate association with the organic reef facies suggests deposition in close proximity to the reef, perhaps a short distance to seaward or leeward of the organic reef, as postulated by Klovan (1964). Turbulence was high during deposition, as is indicated by the fragmented and coarse grained nature of the rocks.

Coral Detritus Microfacies (c)

Lithology: Dolomite, medium brown, occasionally with a greyish hue, fine to medium crystalline, containing as much as 50 per cent "Favosites limitaris". Crinoid fragments are locally abundant, as are massive stromatoporoids. The matrix is predominantly a white dolomite cement (originally spar cement?) and the fragments are roughly of uniform size.

Distribution: This deposit has been found only in one instance, in the basal portion of the Banff Mobil Rainbow West 16-15 well.

Environment: The environment of deposition is interpreted to be similar to the stromatoporoid detritus microfacies discussed above. The well-washed appearance suggests that turbulence was probably moderate to strong.

Back Reef Facies (B)

The distinction between skeletal and non-skeletal microfacies has not been attempted because the recognition of the constituent grains is impossible. Thin sections give some indications, but usually are not conclusive.

Skeletal and Non-skeletal Microfacies (d)

Lithology: Light to medium brown, medium crystalline sucrosic dolomite. Scattered fossil fragments greater than 2 mm in size and including brachiopods, tabulate corals, stromatoporoid fragments and crinoids are present in variable amounts

up to 10 per cent. Much of the coarse skeletal material is represented by leached porosity, making individual recognition of the fragments difficult. Skeletal material less than 2 mm in diameter has not been recognized, although it is presumably present. Inter-crystalline porosity is normally well developed, but occasionally is distributed in patches. Blebs of anhydrite, disseminated pyrite and stylolites are common.

The dolomite crystals are subhedral and vary in size from 0.05 mm to 0.5 mm but average 0.15 mm. The crystals are sometimes zoned, typically exhibiting light coloured centres and dark brown rims (inclusion concentrations). The poorly sorted nature of the particles suggests a skeletal origin. In other instances, subhedral to euhedral crystals of uniform size (0.2 to 0.25 mm) tend to indicate well sorted sediments, possibly non-skeletal (?). This type is not as abundant.

Environment: Interpretation of the environment of deposition requires the recognition of the matrix material. The writer believes that the majority of the material is skeletal, and originally represented a skeletal sand. The skeletal grains would probably have been derived from the attrition of reef organisms. This would suggest proximity to active reef growth. Deposition was probably in a shallow, moderate-energy environment. Turbulence was usually not great enough to transport macro-fossils, but only sand-sized skeletal (?) grains. The occasional presence of non-skeletal (?) material would reflect a slightly restrictive environment, possibly in a further back reef position.

Fore Reef Facies (c)

Reef-flank Detrital Microfacies (e)

Drill cuttings from the northwestern edge of the reef complex, in the Banff Mobil Rainbow West 4-15 well, suggest the presence of a fore-reef facies. The beds consist of dark brown, bituminous and argillaceous (based on gamma ray) dolomite

containing crinoids, brachiopods and unrecognizable skeletal debris. The argillaceous aspect may be due partly to the inter-bedding of this facies with the middle argillaceous unit of the Upper Keg River Member. In core, the facies is represented by a medium to dark brown, fine to medium crystalline dolomite containing a heterogeneous mixture of fragments, both skeletal and non-skeletal. The majority of the large fossils are almost always fragmented, and constitute up to 30 per cent of the rock. The fossils include massive stromatoporoids, corals both rugose and tabulate, and brachiopods. Algal coatings, oncolites, and tabulate stromatoporoids typify this facies. Inclined bedding with dips approaching 20 degrees has been noted in a few instances. Coarse sand and silt commonly make up the groundmass.

Distribution: This facies type is found developed to a minor extent in the upper portion of the Banff Mobil Rainbow West 12-10 well, and probably represents the entire upper portion of the 4-15 well.

Environment: The rocks of this facies are interpreted to consist of detrital components displaced from the reef facies together with indigenous benthonic forms. The rocks indicate deposition in water that was deeper and less agitated than that of the reef facies. The bituminous nature of the rocks (4-15 well) indicate reducing, quiet water.

Basinal Facies (D)

Crinoidal Microfacies (f) (Plate 5, Figure 3)

Lithology: Dark grey brown to black, fine to medium crystalline bituminous dolomite. Crinoid and Thamnopora fragments are scattered throughout, but are common locally in clusters. Several zones are typified by concentrations of large crinoid ossicles which are up to 1 cm in diameter. Tabular stromatoporoids, brachiopods, Stachyodes, oncolites and tabulate corals are rare to common. Generally the skeletal component greater than 2 mm constitutes less than 15 per cent of the rock although beds

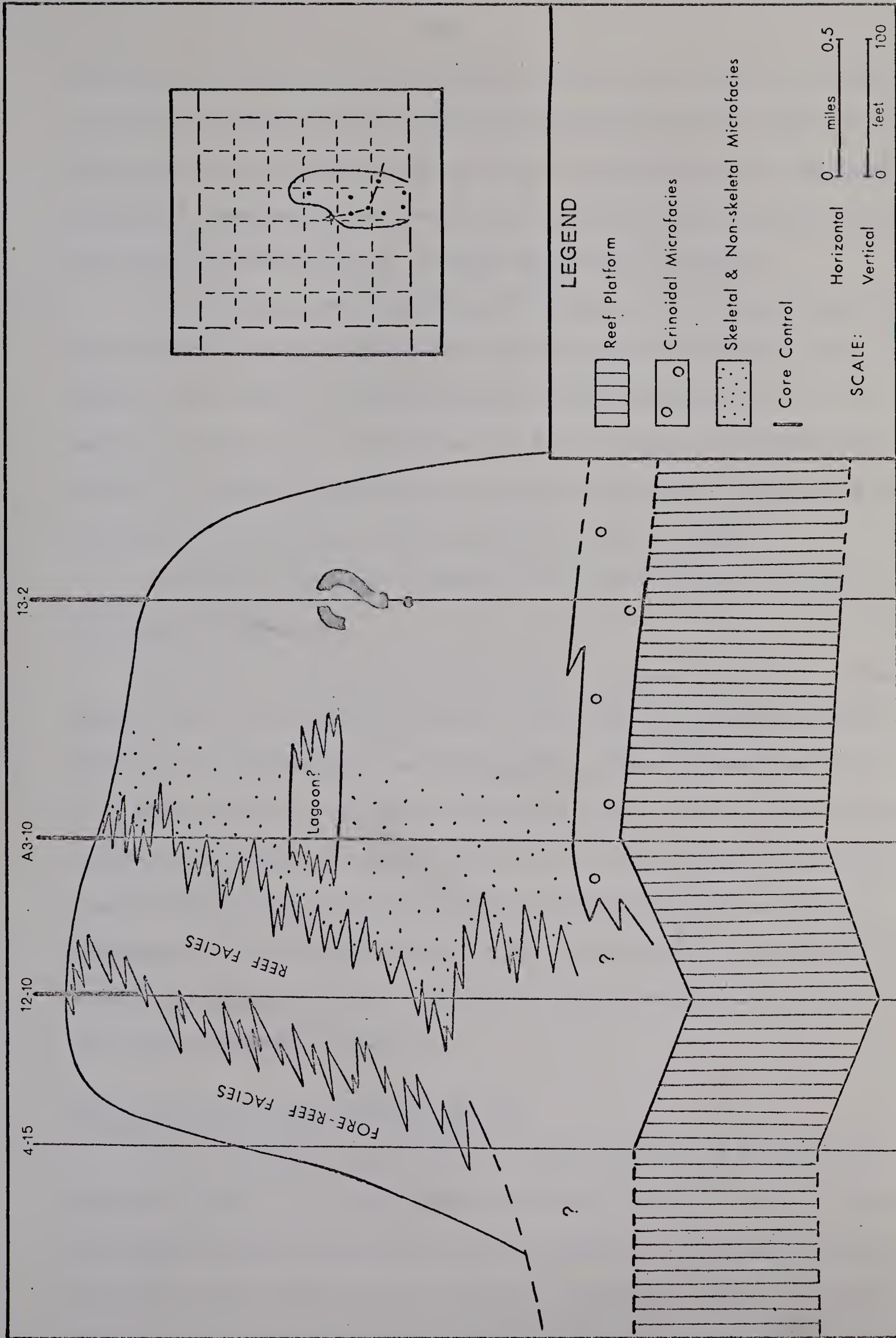


Figure 16. Diagrammatic Facies Distribution of the Lower Rainbow Member, based on drill cuttings.

devoid of coarse (greater than 2 mm) skeletal debris are fairly common, as are beds containing more than 15 per cent skeletal fragments (predominantly crinoid ossicles). One interval was encountered which contained more reefal material such as massive and bulbous stromatoporoids and tabulate corals. Anhydrite infills vugs and replaces the occasional skeletal fragment. Stylolites are abundant throughout.

Crystal size is normally highly variable, ranging from less than 0.05 to more than 0.25 mm in diameter, reflecting the original poorly sorted character of the sediment. The crystals are normally anhedral but tend to become euhedral at the margins of leached vugs. The grains less than 2 mm in diameter are predominantly skeletal, but specific origin of the grains cannot be determined. Several beds contain a well sorted crystal fabric in which ghost pellet textures are visible.

Distribution: The facies is restricted to the base of the Rainbow Member, overlying the platform rocks.

Environment: This rock type is interpreted to represent a bituminous skeletal micritic limestone (the fine crystallinity less than 0.062 mm representing micrite) to biorudite. The abundance of crinoids is thought to represent moderately deep quiet water which favored the establishment of crinoidal meadows. One can infer reducing conditions from the bituminous nature of the rock. The local appearance of stromatoporoids suggest periods of increased turbulence and slightly shallower waters. Their presence may result from the local destruction of patch reefs during periodic storms. This facies could occur in the somewhat deeper parts of the basin, with patch reefs developing on local highs.

Algal Reef Complex (Upper Rainbow Member)

The upper Rainbow Member attains a maximum thickness of 360 feet in the southeastern portion of the reef complex. Three facies and their variants are recognized by analogy with modern carbonate environments (Table 4). Each facies represents a unique depositional setting near mean sea level, specifically: sediments deposited close to mean sea level (intertidal), just below mean low tide level (subtidal), and in

restricted shallow waters(lagoonal). The facies genesis and differentiation is considered to be due to three main factors, namely water depth, wave energy and salinity of the water. There is no sharp break between adjacent facies, but rather a continuous gradation from one to the other. Overlapping of the individual facies, produced by fluctuating environmental conditions, result in a complex facies mosaic.

Each facies and its variant is listed in Table 5 and is briefly discussed in the following pages. Figures 17 and 18 illustrate the distribution of these facies throughout the complex.

Intertidal Facies (A)

The intertidal facies, as the name suggests, is believed to be representative of the interval between high and low tides. In this study, it is taken to include not only the area affected by daily tides, but also the environment of sedimentation that is periodically flooded by tidal extremes during the year.

Pelletoid sands and "algal" sediments dominate this facies and suggest a setting not unlike that of the tidal flat in the Persian Gulf (Illing et al., 1965).

Laminoid Fenestral Carbonates (1)

Type 1 (Plate 5, Figure 11)

Lithology: Limestone, light to medium brown, medium to coarse grained, discontinuously laminated and non-fossiliferous. The laminae are thin (1 to 2 mm), "crust-like", often crinkled and composed of lumps, pellets, and the occasionally calcisphere and skeletal grain. These grains are usually less than 0.3 mm in diameter, but algal lumps up to several centimeters have been observed. The laminae are separated by layers of sparry calcite and/or voids. Vertical fractures are common. Dolomite rhombs are scarce to common, and usually occur concentrated in bands parallel to the lamination.

TABLE 4

Comparison of Upper Rainbow Member with Carbonate Environments.

Upper Rainbow Member	Recent Analogue	Reference
Algal laminated Sediments	Upper intertidal zone in the Persian Gulf	Illing et al. (1965) [—]
Laminated pelletal muds with birdseyes	Mid-tide level to high spring tide level in South Florida	Ginsburg et al. (1954) [—]
Pelletoid sands	Supratidal, Andros Island	Shinn et al. (1965) [—]
Pellets and lumps	Intertidal zone, Persian Gulf	Illing et al. (1965) [—]
	Just below the intertidal zone, Great Bahama Bank	Illing (1954)

TABLE 5

Facies Classification of the Upper Rainbow Member (Algal Reef Complex).

FACIES	MICROFACIES
Intertidal Facies (A)	Laminoid Fenestral Carbonates (1)
	Stromatolites (2)
	Lump-Pellet Limestones (3)
	Medium Crystalline (Pellet) Dolomite (3a)
	Medium Crystalline (Pellet) Skeletal Dolomite (4)
	Gastropod Conglomerate (5)
Subtidal Facies (B)	Skeletal Dolomite (6)
	Stromatoporoid Microfacies (7)
	Dolomite Breccia (8)
Lagoonal Facies (C)	Leached Skeletal (Amphiporoid) Dolomite (9)
	Fine Crystalline (Lime Mud) Dolomite (10)
	Argillaceous Dolomite (11)
Miscellaneous Facies (D)	
	Pseudo-breccia Facies (12)

Type 2

Lithology: Limestone, light to medium brown, fine to medium grained, and finely laminated. The lamination is poor to fair, reflecting a non-alignment of the individual fenestra. The rock tends to be composed of finer grains than type 1. Grains are predominantly lumps with occasional skeletal grains, pellets and calcispheres also being found. Lime mud occurs intermixed with the grains and as interlaminae.

The voids or fenestra are commonly less than 2 mm in size, and are irregularly shaped and isolated, although they may merge to form elongate horizontal "ribbons". The spar cement found within the fenestra commonly show two generations of formation, an early thin lining of radially oriented spar, and a later filling of the remaining central void by coarse granular spar.

Type 3 (Plate 5, Figure 13)

Lithology: Dolomite, light to medium greyish brown, fine to medium crystalline and laminar. Crust-like laminae are outlined by elongate discontinuous voids. The thickness of the "plates" can vary from 5 mm to less than 1 mm depending on the original thickness of the laminae and the extent to which porosity has developed. In the highly porous rocks, the laminae are usually regularly spaced, very thin and continuous. This rock type is also represented by dolomite that is dense and finely laminated. The laminations are due to faint colour banding. Fine fractures are commonly associated with some of these sediments, and may represent desiccation structures.

The matrix is composed of both anhedral and/or euhedral brown smoky crystals, commonly less than 0.1 mm in diameter. Original grain textures are not visible. Laminations are produced by either elongate vugs, or horizontal bands, or by laminae of clear crystals. The laminae or fenestra may be outlined by finer dolomite crystals which, if present, are less than 0.05 mm in diameter. Irregularly shaped non-continuous

fenestra are similarly preserved by patches of light coloured crystals.

Type 4 (Plate 5, Figure 6)

Lightology: Dolomite, light to medium brown and fine to medium crystalline replaced by bands of white coarsely crystalline dolomite. The white dolomite occurs as sub-parallel discontinuous bands, stringers or blebs parallel to the stratification, and as birdseyes. The percentage of white dolomite is highly variable, although it is normally less than 20 per cent. The shape, size and distribution of the white dolomite is similar to the open and/or spar filled voids of the limestones described above. In many instances it is difficult to differentiate this rock type from stromatoporoid replacement.

The host dolomite is composed of an interlocking mosaic of anhedral to subhedral dolomite of crystal size varying from 0.05 to 0.40 mm (average 0.15 mm) in diameter. The white dolomite occurs as coarse euhedral strained crystals. Original grain textures cannot be recognized.

Fossils: Minor amounts of Amphipora, gastropods, brachiopods, and ostracods make up the fauna.

Distribution: These sediments are most common in the northern and lagoonal portion of the complex. Associated with these sediments are thin interbeds of lime silt and mud containing the occasional Amphipora, Stachyodes, and Thamnopora.

Environment: The laminoid fenestral carbonates are considered to represent the upper portion of the intertidal zone, even though the distinctive fabric can be interpreted as representative of various other sedimentary environments (for a complete discussion of this fabric refer to Tebbutt et al., 1965). Recognition of the facies depends on the interpretation placed on the origin of the fabric. Fischer (1964) interprets the structure (loferites) as representing desiccation voids formed in intertidal sediments (the term intertidal also includes the supratidal environment). A similar interpretation for nearly identical sediments has been given by Laporte (1967), but he considers

them to have formed in the supratidal environment. His interpretation is based on similarity with the recent supratidal dolomite crusts at Andros Island (Shinn et al., 1965). Klován (1964) believes that the fabric (laminite) may reflect the influence of algal mats during sediment accumulation, and represents deposition in the intertidal zone. Klován (1964) reaches his interpretation by analogy with similar sediments presently accumulating on Andros Island and along the southern coast of Florida. The writer feels that both processes (shrinkage and algae) were responsible for the genesis of the laminoid fenestral structures and that their formation has taken place both in the intertidal and lower, periodically-wetted, supratidal realm.

Stromatolites (2)

Type 1 (Plate 5, Figure 9)

Lithology: Limestone, medium brown (oil stained), fine to medium grained, and laminar. Laminations are formed by alternating calcite rich and bitumen rich (algal?) layers. The bituminous laminae are usually thin, irregular and subparallel. The laminae contain dispersed pellets as well as occasional unidentifiable skeletal and algal grains (Dasycladacean?), which are normally less than 0.2 mm in diameter. Micrite is abundant to dominant.

Dolomite crystals frequently are present as stratified "laminae" replacing the bituminous layers.

Type 2

Lithology: Dolomite, commonly calcareous, medium brown, very finely crystalline and finely laminar. The laminations range from one-quarter of a millimeter to several millimeters in thickness, and are regular to distorted in appearance. They are commonly inclined or hemispherical and resemble the close spaced linked hemispheres of Logan et al., (1964). Each lamina is separated from adjacent laminae by a thin dark organic (?) film which may represent the remains of algal mats.

The rock usually has good intercrystalline porosity.

Type 3

Lithology: Limestone, light to medium brown, fine to medium grained and laminar. Laminations result from alternating bands of cryptocrystalline calcite with lime silt and mud. The cryptocrystalline bands are normally less than 4 mm thick.

Dasycladacean algal stems and branches are abundant.

Fossils: No macrofossils were found with any of these sediments.

Distribution: This facies is restricted to the upper beds of the southernmost wells. It represents only a very minor portion of the reef complex. This rock type is occasionally interbedded with thin beds, less than 6 inches thick, of cryptocrystalline calcite containing abundant calcispheres.

Environment: This distinctive rock type is interpreted as having been deposited by algal mats in the upper tidal flat environment. This is based on analogy with recent accumulations in South Florida. In this region, laminated algal sediments are found forming from about mid tide level to the level of high water spring tides (Ginsburg *et al.*, 1954). Type 3 is not a true stromatolite, but is included with them for purposes of discussion. The lamination in this type is interpreted as having been formed by the alteration of organic precipitation caused by algae, with mechanical deposition.

Lump-Pellet Limestones (3)

Lithology: Limestone, light to medium brown, fine to medium grained, and non-laminar. The beds are sometimes mottled by bituminous material making it difficult to recognize the framework constituents, particularly in the micritic sediments.

The framework consists predominantly of lumps and pellets, with occasional calcispheres and unidentifiable skeletal grains (Plate 2, Figure 5). Oolites are absent. The grains are poorly sorted, ranging in size from less than 0.05 mm to more than 2 mm. The larger grains are commonly surrounded by a dark rim similar to the

grains described by Illing (1954, p. 26 to 35). The groundmass is spar with minor amounts of micrite. In the micritic sediments, bituminous material occurs in both the matrix and constituent grains, making it difficult, even in thin section, to recognize individual grains. In the spar-cemented rocks, the bituminous material is dispersed throughout individual grains, but has frequently been redistributed towards the margins, by internal recrystallization (?). Not all grains are bituminous resulting in a mottled appearance. Dolomite, either as individual crystals or "clusters" preferentially replaces these bituminous-rich grains.

Fossils: A sparse assemblage of fossils is associated with these sediments. They include ostracods, gastropods, Amphipora, Thamnopora, Stachyodes, brachiopods, and corals.

Medium Crystalline (Pellet) Dolomite (3a) (Plate 6, Figure 5)

Lithology: Dolomite, light to medium brown, medium crystalline, non-laminar, characterized by an absence of fauna. In some portions fossil textures (less than 5 per cent) are suggested by subtle colour variations, resulting in a slightly mottled appearance. A mottled appearance also results from irregularly shaped patches of intercrystalline porosity. Certain portions of this facies are highly fractured and are replaced by anhydrite, resulting in a brecciated appearance. White dolomite replacement occurs only in minor quantities usually less than 5 per cent. Porosity, both intercrystalline and vuggy is normally poorly developed.

The rock consists of "well-sorted", subhedral to euhedral dolomite crystals 0.2 to 0.3 mm in diameter. Some thin sections display vague outlines of pellets and lumps. Where thin sections are not available a pellet texture can only be inferred. Many of the rocks are considered to be pelletal because of the size of crystallinity and porosity development as well as thin section study. Other interpretations may be equally valid.

Distribution: The pelletoid carbonates form a major portion of the upper reef rocks. They are found interbedded with both laminoid fenestral carbonates and skeletal reefoid beds.

In the upper limestone portions of the reef, skeletal micritic limestones occur as thin interbeds. The skeletal material is normally less than 2 mm in size, with only 5 per cent of the fragments greater than 2 mm. These rocks form a distinctive microfacies, but are not differentiated since they cannot be recognized in the dolomites. For similar reasons no distinction is made between the pellet and lump limestones.

Environment: This rock type may be interpreted as representing deposition in the intertidal to subtidal environment. In the Recent, similar sediments are forming on intertidal flats in the Persian Gulf (Illing *et al.*, 1965). and below the intertidal zone in South Florida and on the Great Bahama Bank.

The distinction between the two environments must be based on the association with skeletal or algal beds. The preservation of bituminous material (limestones) indicate incomplete oxidation and suggests periods of reducing conditions on intertidal flats.

Medium Crystalline (Pellet) Skeletal Dolomite (4)

Lithology: Dolomite, light to medium brown, medium crystalline, non-laminar and containing more than 2 per cent but less than 10 per cent biogenic material greater than 2 mm in size. Occasionally the groundmass is finely crystalline indicating an original micritic matrix or a zone which has been more intensely dolomitized. The skeletal texture is usually poorly preserved due to extensive leaching and replacement by white dolomite. Replacement white dolomite occurs as elongate "blebs" less than 5 mm in length, either randomly dispersed (polka-dot texture) or horizontally strung, resulting in a bedded appearance. Some of the white dolomite forms have a skeletal appearance (biogenic texture).

The dolomite crystals are normally 0.2 mm to 0.3 mm in diameter and are subhedral. Skeletal grains are suggested by finely crystalline patches having a skeletal form. The matrix is considered to be pelletal, although lime mud and skeletal grains are probably present in varying proportions. Identification of the constituent grains is generally impossible.

Fossils: Scattered gastropods, brachiopods, pelecypods, and corals comprise the fauna of this facies.

Environment: Deposition took place in an environment that was transitional between rock types (3) and (6). The facies designation includes a mixed environment containing pellet (?) interbeds with skeletal debris in a probably pellet matrix.

Gastropod Conglomerate (5) (Plate 6, Figure 8)

Lithology: Dolomite, medium brown, composed entirely of gastropods (framework supporting). The gastropods (Murchisonia) are preserved as internal molds or steinkerns in beds less than 3 feet thick.

Distribution: Only two beds at the Banff Mobil Rainbow West 13-2 well were encountered.

Environment: These shell banks are interpreted as beach sediment or concentrations within shallow tidal creeks.

Subtidal Facies (B)

The subtidal facies was deposited beyond the intertidal flats in increasingly deeper and more off-shore waters. It is characterized by fragmented fossiliferous carbonates and massive pelletal beds containing stromatoporoids and corals. The reefoid nature is poorly developed and suggests unfavourable environmental conditions.

Skeletal Dolomite (6) (Plate 6, Figure 6)

Lithology: Dolomite, light to dark brown, fine to medium crystalline and

containing more than 10 per cent skeletal debris greater than 2 mm in size. The percentage of fossil material seldom exceeds 30 per cent, and for this reason no frame-supporting organic facies is proposed. The facies is typically non-bedded and has a fragmented appearance. Coarse white dolomite replacement is common, and is normally in skeletal or polka-dot form.

The rocks is represented by poorly sorted, anhedral to subhedral dolomite crystals, with little or no relict textures. The crystals average 0.25 mm in diameter, and range from 0.05 to 0.50 mm. Some skeletal grains may be present as coarse (greater than 0.50 mm) ragged crystals.

Fossils: Fossil material includes fragments and whole specimens of Stachyodes, Thamnopora, tabulate, septate and rugose corals, gastropods, pelecypods, brachiopods, and stromatoporoids. Some of the fossils have algal overgrowths. Frequently the fossils can only be identified by gross morphology (shell fragments, cup coral), while in many cases it is impossible to recognize the individual fragments owing to severe leaching and extensive replacement by white dolomite.

Distribution: This rock type represents a substantial portion of the sediment in the southern portion of the complex.

Environment: The rocks of this microfacies are interpreted as representing broken-up organic reef material deposited a short distance away in quiet shallow water. It can also be interpreted to have been deposited in the shallow intertidal zone by periodic storms.

Stromatoporoid Microfacies (7) (Plate 6, Figure 4)

Lithology: Dolomite, light to medium brown, medium crystalline and massive. The stromatoporoids occur as individual bulbous and/or massive forms up to 5 inches in diameter. They are usually poorly preserved, with their presence suggested by curvilinear, hemispherical and "plate-like" leached vuggy and intercrystalline porosity. The stromatoporoids are found floating in a pellet (?) mud, in contrast to the well washed sediment matrix of other reefs (Klovan, 1964). White dolomite is commonly present, either replacing the stromatoporoids or irregularly replacing zones immediately

above or below recognizable stromatoporoidal material. These associated zones of white dolomite may reflect organic material that has been replaced to such an extent that the textures are obliterated.

Distribution: These deposits are found in the southern portion of the reef. They seldom form thick beds, and contribute only a small portion to the entire complex.

Environment: The stromatoporoidal beds do not have the scale of "reef", even though they probably formed small wave resistant structures. The muddy matrix suggests becalmed waters. The poor development of this facies is attributed to unfavorable environmental conditions, caused by a restriction of the basin by barrier reefs in the west, resulting in increased salinities and lowered oxygen content.

Dolomite Breccia (8) (Plate 6, Figure 3)

Lithology: Dolomite, light to dark grey brown, fine to medium crystalline dense, massive and brecciated. The fragments or lithoclasts greater than 2 mm are variable in colour, size, and shape, and seldom form more than 20 per cent of the rock. They are normally subrounded, and less than 1 mm in size, although they may be both angular or rounded and up to 6 cm in diameter. Some of the fragments are brecciated themselves indicating reworking. The matrix consists of sand, silt and clay-sized dolomite grains. Anhydrite is frequently dispersed throughout, but in many instances cannot be recognized except in thin section. Included in this facies are thin interbeds of dark grey brown, finely crystalline dolomite containing little or no dolomite fragments greater than 2 mm. Some of these interbeds are composed of sand-sized fraction, while other beds contain no recognizable grains (originally a lime mud?).

The matrix is composed of poorly sorted dolomite crystals which are often euhedral. The crystals vary in size from 0.05 to 0.30 mm and are cemented by finely disseminated anhydrite (based on only one thin section). The fragments are commonly finer crystalline and non-anhydritic.

Distribution: This facies is found predominantly in one well along the western edge of the complex, where it makes up a substantial portion of the entire interval. Thin beds also occur in other localities, but not in any significant quantity. Associated with this facies are interbeds of primary (?) anhydrite.

Environment: These rocks may be interpreted as representing partially lithified mud torn up from the sea floor along tidal channels or unprotected mud flats, and deposited in quieter water (intraclasts). The interbeds of dark grey brown finely crystalline dolomite are thought to represent lime mud deposited during periods of quiescence, or possibly in somewhat deeper water. The breccias may also be interpreted as having formed by the desiccation of previously deposited carbonate sediment and later reworked by wave action. The former interpretation is considered to be the most important in the formation of this facies since it occurs along the western margin of the reef where wave activity was probably at its maximum (direction of the open sea).

Lagoonal Facies (C)

Rocks of the lagoonal facies were deposited in a shallow semi-restricted body of water. Lime muds, occasionally with amphiporoids, formed in the quiet, continuously submerged central portions, while periodic wettings along the upper margins of the lagoon favoured the development of laminoid fenestral carbonates. The salinity of the waters in the lagoon was apparently higher than normal, judging from the absence of normal marine fauna.

Leached Skeletal (Amphiporoid) Dolomite (9) (Plate 6, Figure 1)

Lithology: Dolomite, light to medium brown, fine to medium crystalline non-laminar, and characterized by leached skeletal vuggy porosity. The vugs are typically round and elongate, 1 to 4 mm in diameter, and up to 3 cm long. In the majority of cases, there are no relict fossil remains. The voids constitute as little as 2 per cent to more than 10 per cent of the rock, reflecting the percentage of

biogenic material present. The size, shape and distribution suggest that the voids represent leached amphiporoids. This conclusion is supported by the recognition of Amphipora in a few of the beds. Porosity in the rocks is reduced by clear anhydrite crystals and "pyrobitumen" lining and infilling the vugs. Permeability tends to be poor, as the voids are seldom interconnected. Pinpoint porosity is common throughout.

The matrix is composed of an interlocking mosaic of brown anhedral dolomite crystals, commonly 0.2 mm in diameter. The crystals become larger and euhedral at the edges of the leached organic vugs, and are commonly of a lighter colour.

Distribution: This rock type is found in beds one to two feet thick interbedded with laminoid fenestral carbonates and dense lime muds (?). It is most abundant in the central portion of the reef complex, where cross-sections and maps indicate that the reef is low.

Environment: A shallow, semi-restricted environment is envisioned for this distinctive rock type. The uniform crystallinity of the matrix suggests an original well sorted sediment, such as a pellet lime mud or lime mud.

Fine Crystalline (Lime Mud) Dolomite (10) (Plate 6, Figure 10)

Lithology: Dolomite, very fine to finely crystalline, medium brown to medium grey brown, dense and occasionally mottled.

Dolomite crystals are well sorted, euhedral to subhedral and less than 0.15 mm in diameter.

Distribution: This microfacies occurs sporadically interbedded with amphiporoid and pelletal dolomites throughout the complex, but only assumes significant proportions in the Banff Mobil Rainbow West A3-10 well.

Environment: The dense finely crystalline nature of the dolomite is taken to indicate a lime mud (?), while the greyish cast in some of the rocks is interpreted to suggest small amounts of finely disseminated organic or argillaceous (?) material.

These deposits are thought to represent sedimentation in quiet lagoonal waters. The general absence of fauna indicates that conditions were not favourable for the establishment of a faunal community.

Argillaceous Dolomite (11) (Plate 6, Figure 10)

Lithology: Dolomite, dark grey to bluish grey, very finely crystalline, argillaceous, non-laminar and pyritic. Anhydrite occurs both as irregular lenses and veinlets. No macro- or microfossils are evident. Stylolites are abundant.

Dolomite crystals are euhedral, less than 0.05 mm in diameter and are surrounded by a matrix of organic and argillaceous (?) material.

Distribution: Several beds less than 3 feet thick occur in most wells. In all but four of the wells, two beds are situated in similar stratigraphic positions (time markers?). They are located 40 to 45 feet apart, and 350 to 420 feet (to the top of the first bed) below the top of the Muskeg Formation.

Environment: These beds are interpreted to represent dolomitized "shale" or argillaceous limestones, which accumulated as terrigenous clastics in tranquil bodies of water. Other interpretations (insoluble residues left by solution of carbonate rock during erosion and a volcanic source) are equally valid.

Miscellaneous Facies

Pseudo-brecciated Facies (12)

The pseudo-breccia texture has been discussed in an earlier section. It forms a distinctive rock "facies" in the Banff Mobil Rainbow West 12-3 well. The origin of this lithology is not known, but its abundance necessitates inclusion in this classification.

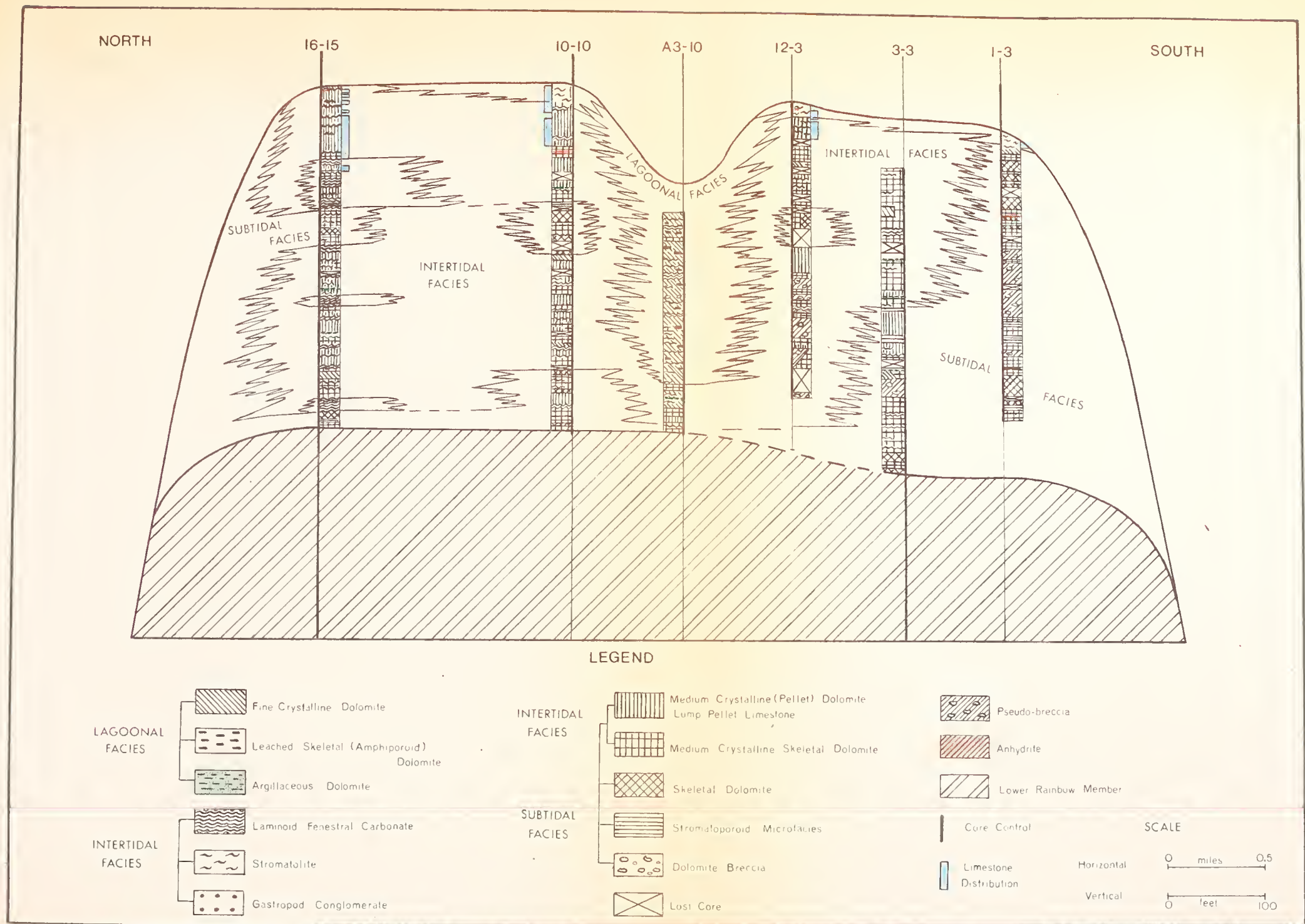


Figure 17. North South Facies Distribution in the Upper Rainbow Member

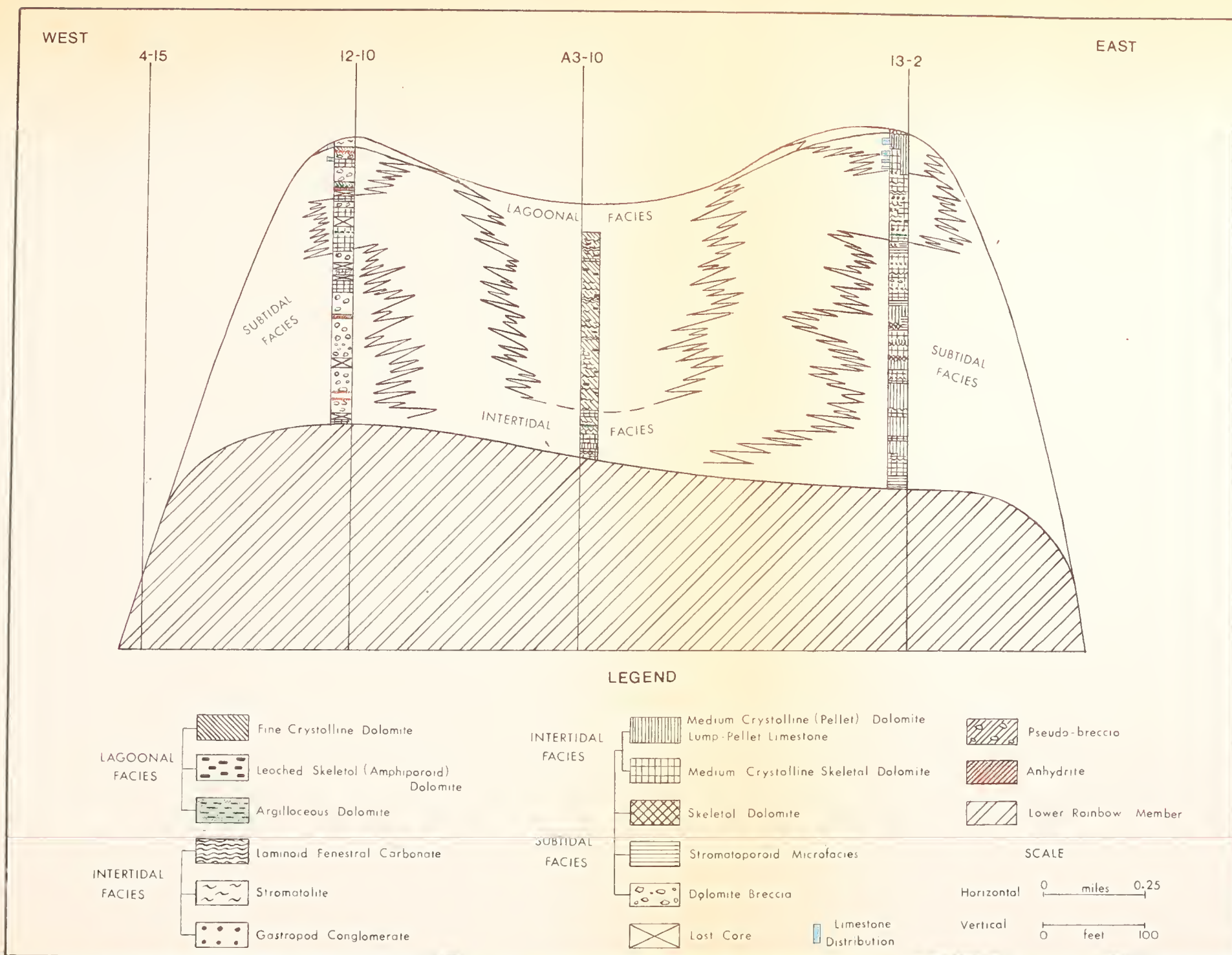


Figure 18. East-West Facies Distribution in the Upper Rainbow Member

DEVELOPMENT OF THE RAINBOW B POOL REEF COMPLEX

The depositional sequence of the Rainbow B pool reef complex has been divided into 4 major stages as shown in Figure 19. The stages are based on distinct changes in lithology and fossil content, and as such represent the most important phases in the development of the reef complex. The interpretation of these events are presented below:

Stage 1

The reef platform was deposited during the initial transgression of the Middle Devonian seas, with sedimentation taking place in quiet relatively shallow water. The uniform nature and widespread distribution of these deposits, indicate that stable conditions prevailed for long periods of time over much of the region.

Warping of the platform beds, through faulting, created local topography on the sea floor. On the local highs, "mound-reefs" developed, while, in the deeper protected waters, crinoidal meadows formed. The reef mounds never formed wave resistant features, as there is no evidence in any of the rock of an organically bound fabric. The local concentrations of reef builders, notably tabular stromatoporoids and corals suggest periods of excessive turbulence which resulted in the destruction and possible migration of the mounds.

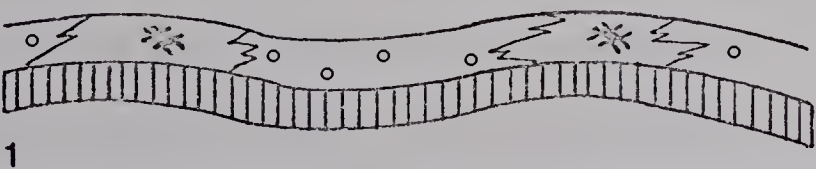
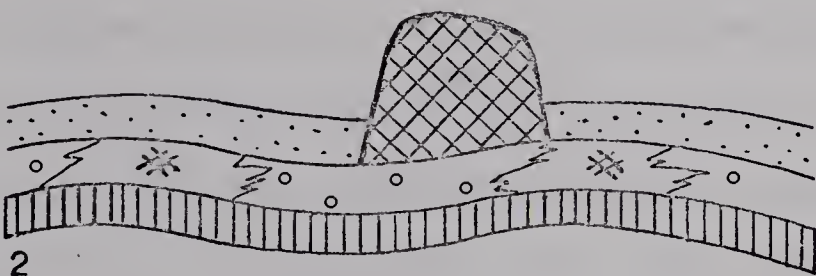
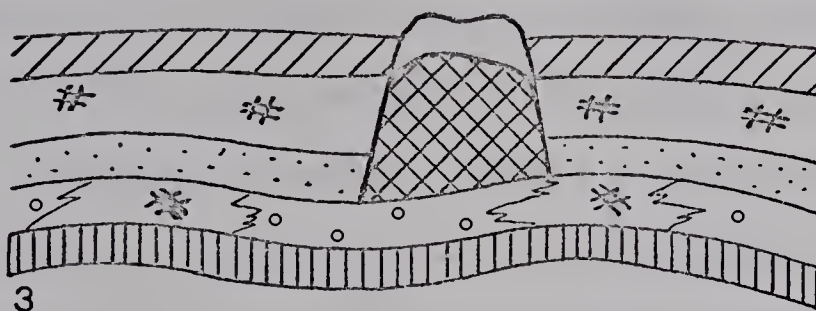
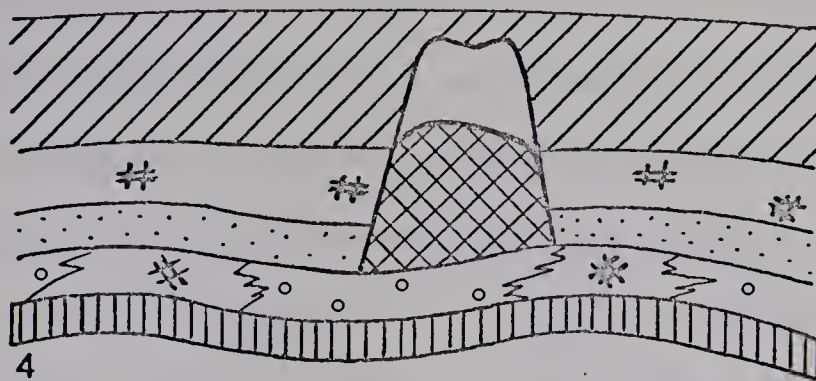
Stage 2

During Upper Keg River time, reef growth was initiated resulting in the development of a patch reef. At this time other reef complexes such as the A Pool reef, Saka, and Tsuhæ are thought to have begun their upward development.

The interpretation of the lower portion of the B Pool reef is complicated by faulting, which evidently began at the onset of platform deposition and ended sometime prior to upper Rainbow sedimentation. The B Pool reef appears to have developed in

West

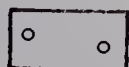
East



LEGEND



Reef Platform



Crinoid Bioclastic



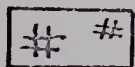
Patch Reef



Organic Reef Complex



Inter-reef Carbonates



Salt



Anhydrite-Dolomite



Shallow Water Carbonates

Figure 19. Development of the Rainbow B Pool Reef Complex

an area of increased subsidence, resulting from down-faulting. Apparently reef organisms were able to build and maintain a wave resistant structure in these more negative area. The organic reef grew along the seaward margin in the zone of turbulence, while skeletal and non-skeletal sands were deposited and formed in the deeper protected waters of the back reef. In the inter-reef positions, lime muds were deposited contemporaneously but at a slower rate than reef growth.

The end of stage 2 is marked by an abrupt change in the depositional environment. This is indicated by a sudden disappearance of frame-building reef organisms, and the appearance of shallow water carbonates. This might be explained by a rapid increase in salinity, accompanied simultaneously by a decrease in water depth.

Two interpretations, based on the relationship of the Keg River reefs to the Muskeg sediments, may be proposed to explain the further development of the reef complex. The explanation furnished by Hriskevitch (1966) is the most readily acceptable. Hriskevitch considers the deposition of the Muskeg Formation (Black Creek Member) to be post reef growth (Rainbow Member), inferring that a change in environment from a normal marine to an evaporitic environment was responsible for the termination of reef growth. In this interpretation, the upper carbonates (upper Rainbow Member) would represent a transitional period between the normal marine organic reef complex and the deposition of salt. Another interpretation not yet presented, would have the upper Rainbow Member syndepositional with the anhydrite-dolomite strata of the Muskeg Formation. This interpretation is presented below (stage 3) and should be regarded only as a modest attempt to stimulate further discussion.

Stage 3

Growth of the organic reef complex (lower Rainbow Member) ended with the evaporitic conditions leading to salt deposition (Black Creek Member). An influx of fresher waters ended the formation of salt, and created conditions favourable for the deposition of Muskeg anhydrite-dolomite strata. At various times during the deposition

of the upper Muskeg, downwarping of the barrier reef to the west allowed the inflow of normal marine waters and perhaps the escape of saturated brines. The influx of fresh surface waters provided the necessary conditions for the growth of reef-like mounds on the crests of the previously established patch reefs. When the barrier reef had been re-established to check the inflow, the mound reefs were killed by the increasing salinities, however, prior to burial by Muskeg evaporites renewed downwarping started them growing again. The development of the reef mounds requires normal to near normal marine conditions, and therefore would be restricted to a narrow belt directly behind the barrier reef, where waters were fresh enough to support colonies of algae and other organisms. This suggestion was substantiated by the fact that no mound reefs have been discovered east of the 6th meridian, although future exploration may reveal their presence. Other evidence suggesting a synchronicity of Muskeg sediments with the upper Rainbow Member are: (a) an abrupt deficiency of fauna, especially massive stromatoporoids in the upper Rainbow Member; (b) an abundance of primary (?) anhydrite interbedded with the mound reef carbonates; (c) a lack of any significant erosion at the top of the reef; and (d) the shallow water character of the Muskeg sediment overlying the reef (after Murray, 1964).

Stage 4

Death of the reef may be attributed to highly saline conditions as postulated by Hriskevitch (1966) or to a decrease in basin subsidence and final burial by Muskeg evaporites.

CONCLUSIONS

1. Dolomite reefs can be effectively investigated by subsurface cores, but conclusions drawn from their examination are less specific than for limestone reefs previously described in the literature.
2. The Rainbow Member can be subdivided into two informal stratigraphic units on the basis of lithology and paleontology, each representing a significantly different depositional environment.
3. The lower reef unit can be subdivided into fore-reef, organic reef, and back-reef facies. The upper unit can be treated as a shallow water carbonate complex forming in the intertidal, subtidal, and lagoonal environments.
4. The fossil assemblages found in the reef complex are believed to be primarily facies controlled, hence are useful for mapping facies, and for environmental interpretations.
5. At least two stages of dolomitization are responsible for obliterating rock textures and structures. The majority of the dolomite is thought to represent an early stage of dolomitization formed by a process similar to that postulated by Deffeyes et al., (1965) at Bonaire. A late stage dolomite further obliterates rock fabric. It is characteristically white, coarsely crystalline and found in distinctive forms which are useful for descriptive purposes. Porosity and biogenic material appear to be the controlling factors responsible for the distribution of this dolomite.
6. The size and sorting of the dolomite crystals are thought to be a direct function of the original granularity and sorting of the limestones, and are useful for the determination of original rock types.

7. From a study of isopach maps, structural maps and cross-section, the following observations are made:

- a) the location of the reef is related to structural activity.
- b) the thickest portion of the complex occurs in the north and west, corresponding to the area of maximum subsidence and reef growth.
- c) the upper reef member is flat-topped, with a prominent depression or lagoon in the central portion of the complex.
- d) the lower reef member is a wedge shaped carbonate complex with a steep fore-slope and a gentle back slope.

8. Correlation between reef and off-reef sections has not been established. Two interpretations may be postulated, in which a) the Muskeg Formation was deposited in post-Rainbow Member time, and b) the upper member of the Muskeg Formation was deposited synchronously with the upper portion of the Rainbow Member.

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EXPLANATION OF PLATE 1

Paleontology

- Figure 1. Oblique sections of Stringocephalus cf. obesus with reconstructed profile. 1a) Pedicle valve; 1b) Junction of pedicle valve (P) with brachial valve (B); 1c) Brachial valve; 1d) Diagramatic sketch showing the interpreted positions of the slices. The cardinal process and medial septa are indicated by cross-hatched lines, and the thickness of the shell by solid shading. (X1)
- Figure 2. Murchisonia (?) (Location 13-2-109-8W6, 5865').
- Figure 3. Photomicrograph: Dasycladacean algae. (Location 10-10-109-8W6, 5812'). (X20)
- Figure 4. Photomicrograph: Transverse section of a bryozoan (Cheilotrypa?) (Location 3-3-109-8W6, 6512'). (X25)

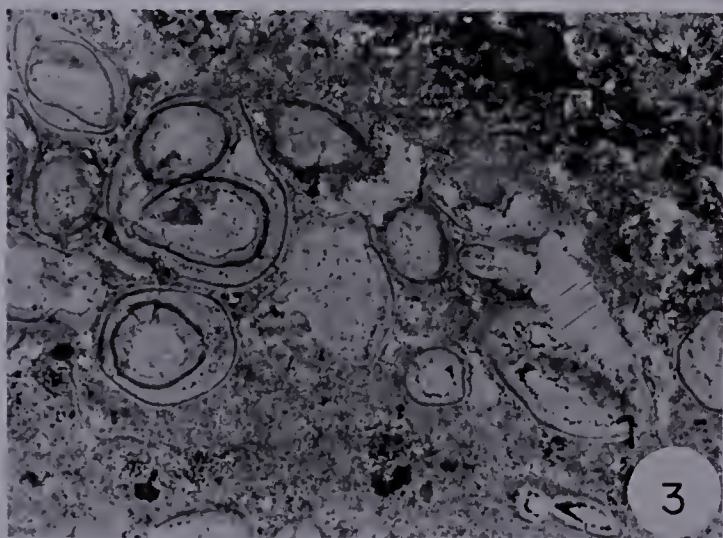
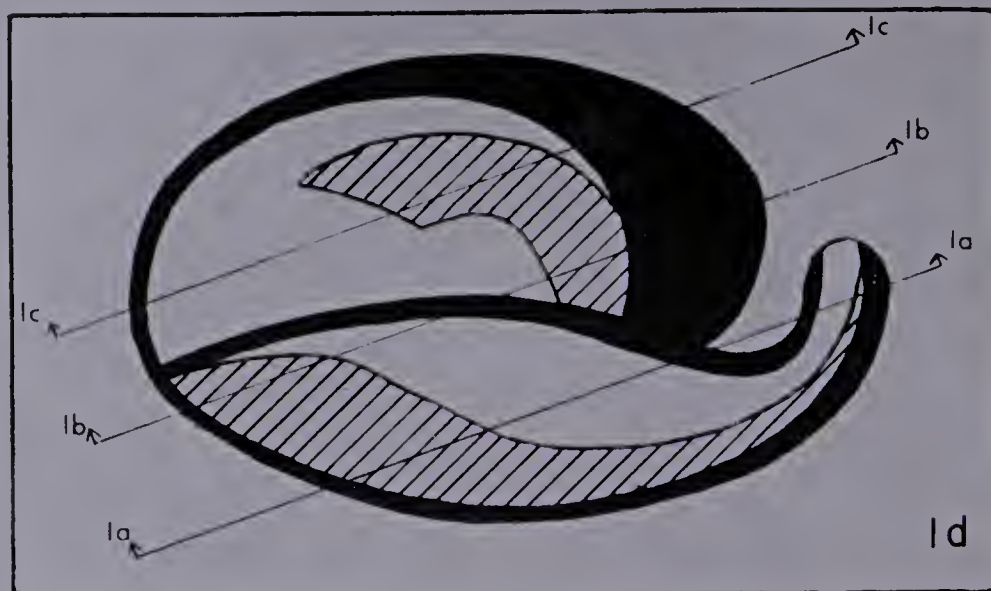
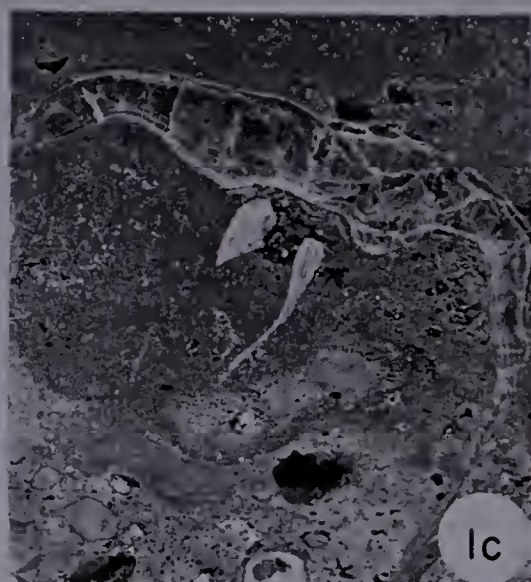
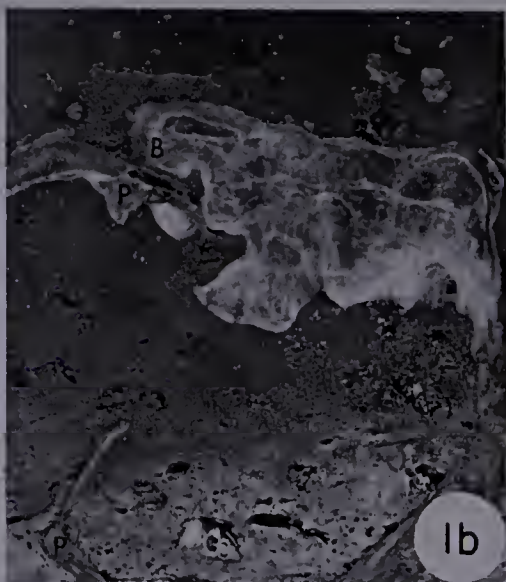
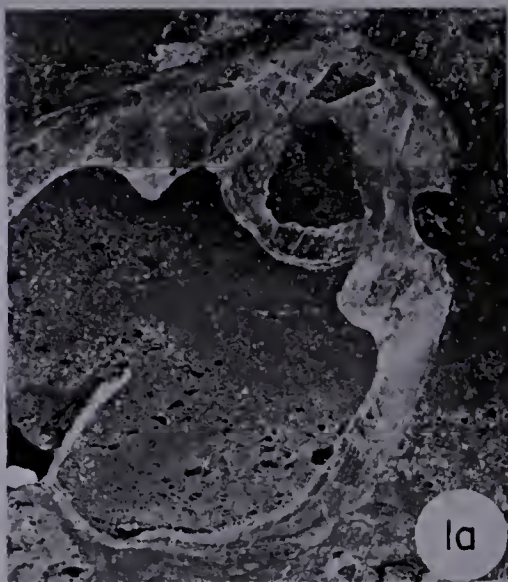
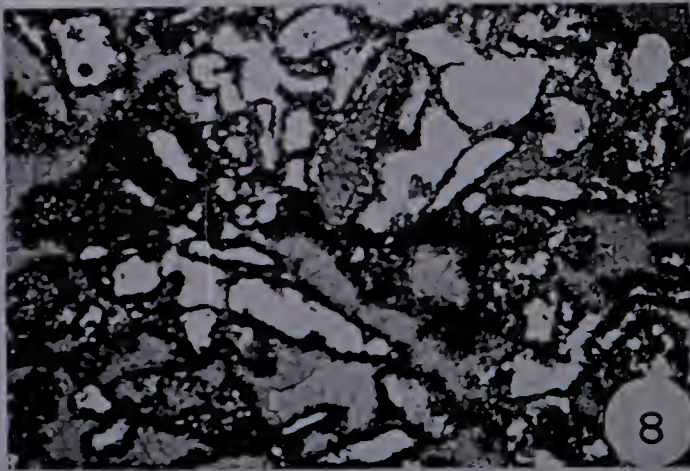
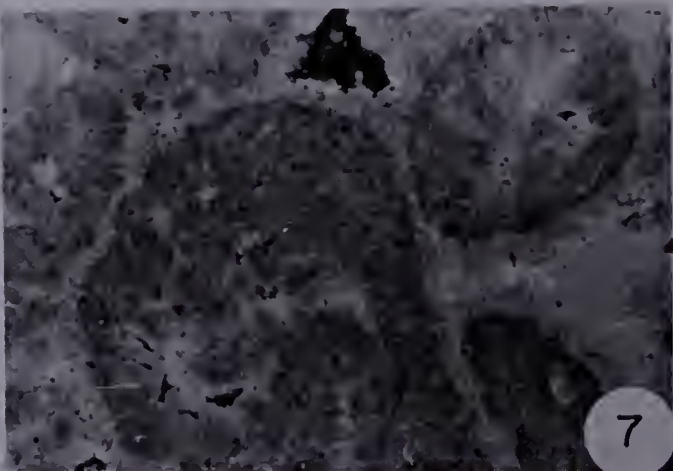
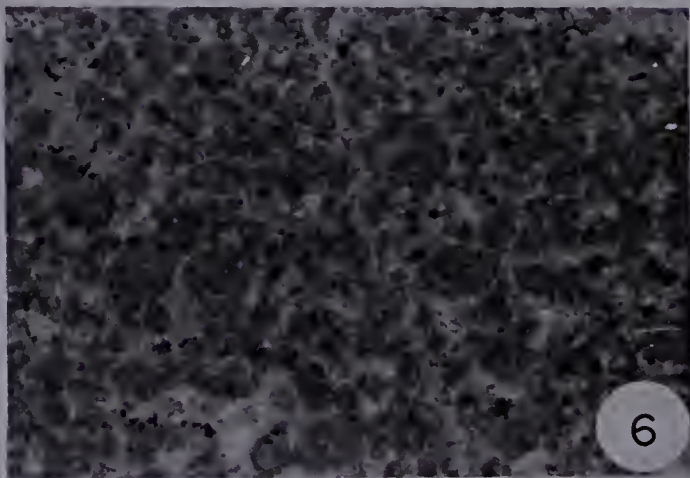
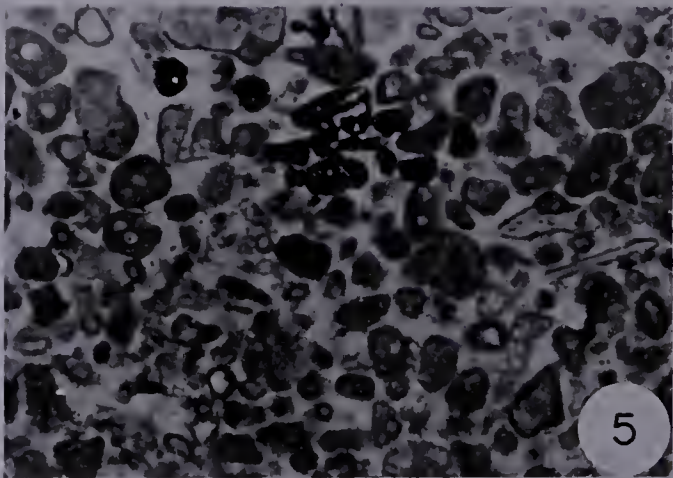
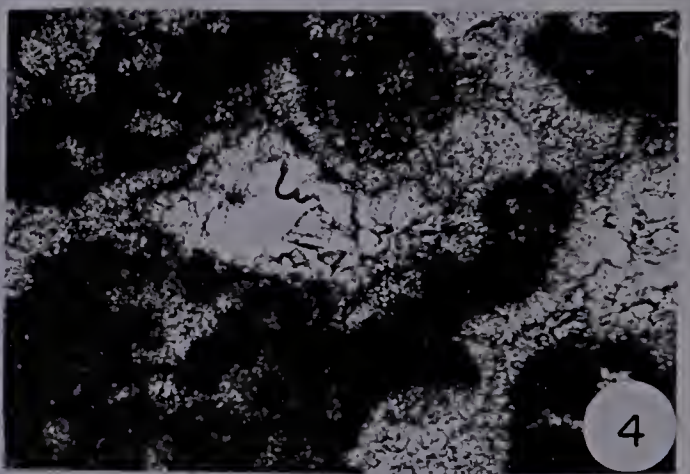
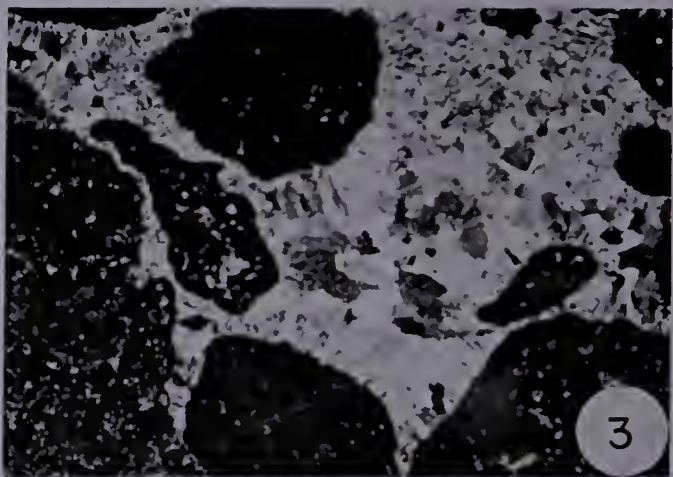
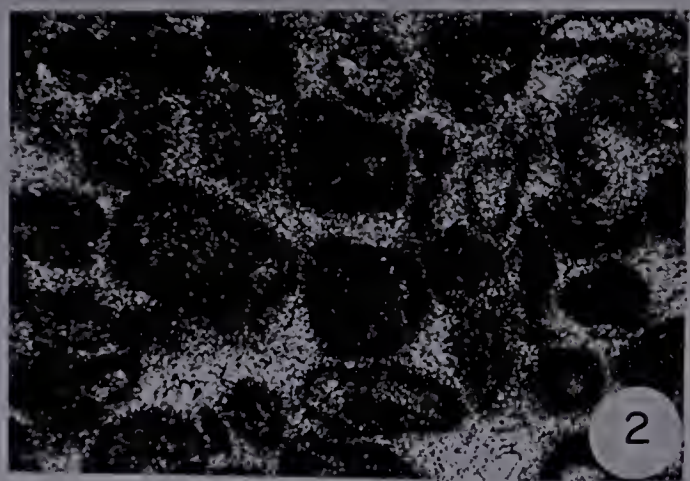
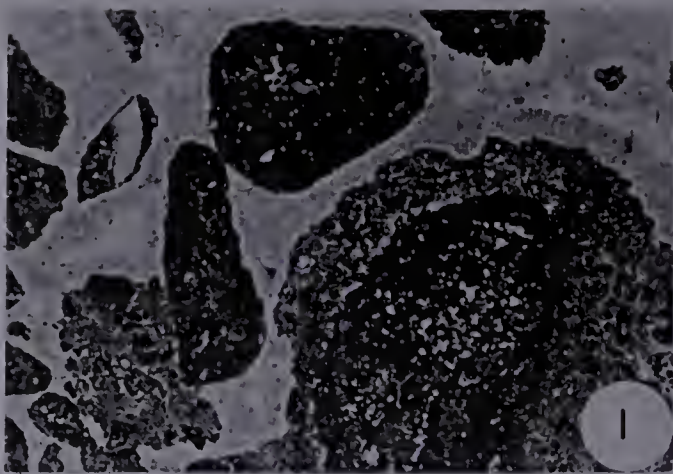


PLATE I.

EXPLANATION OF PLATE II

Petrography

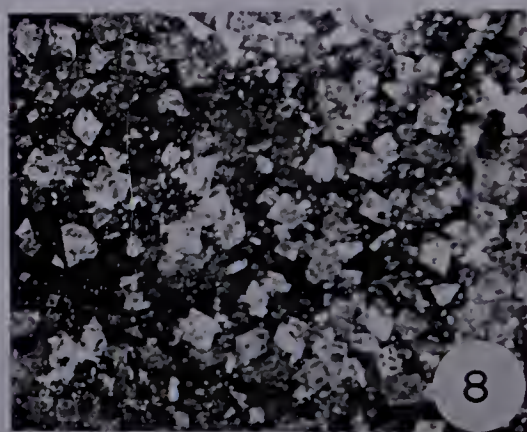
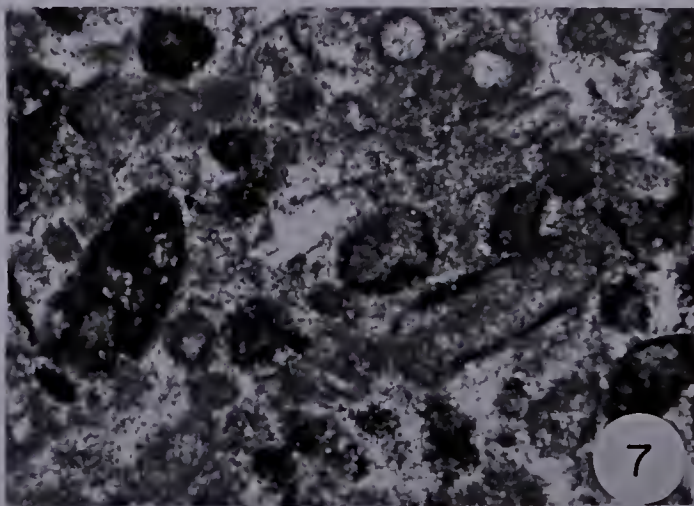
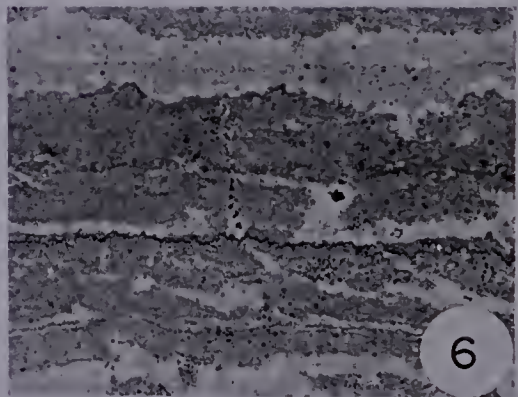
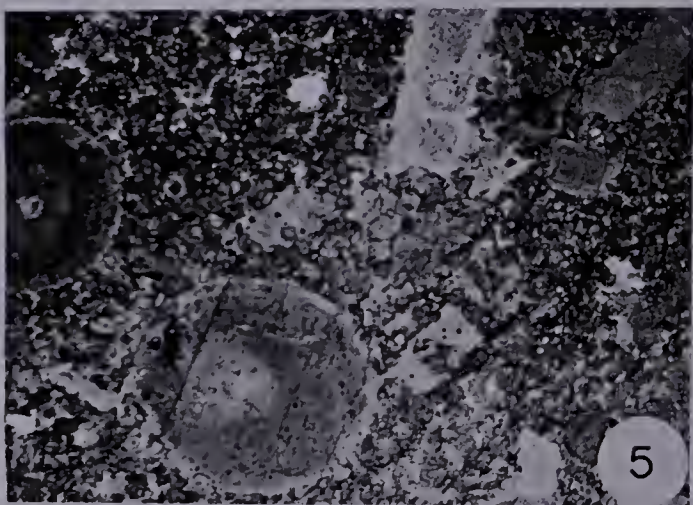
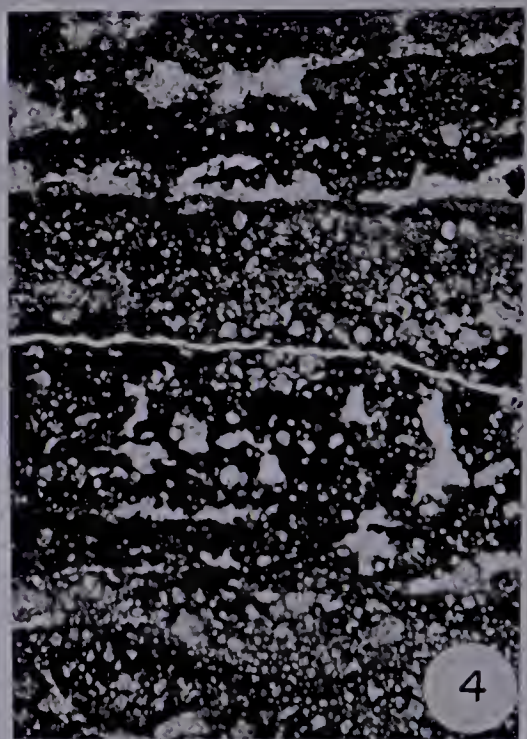
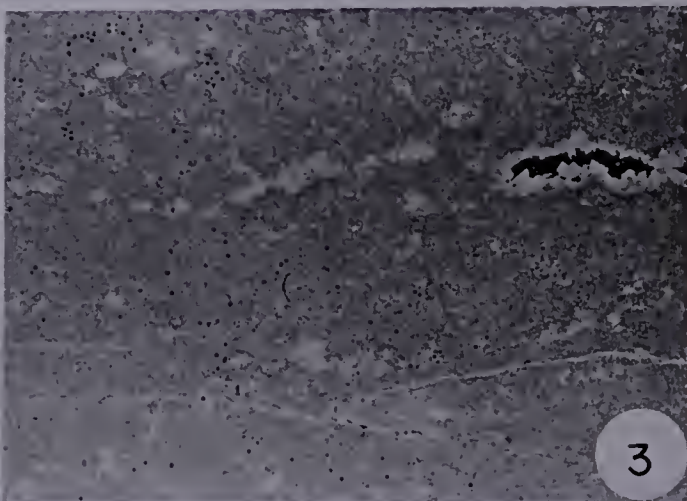
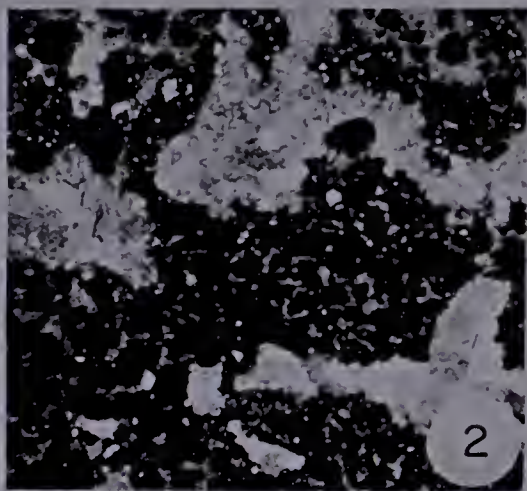
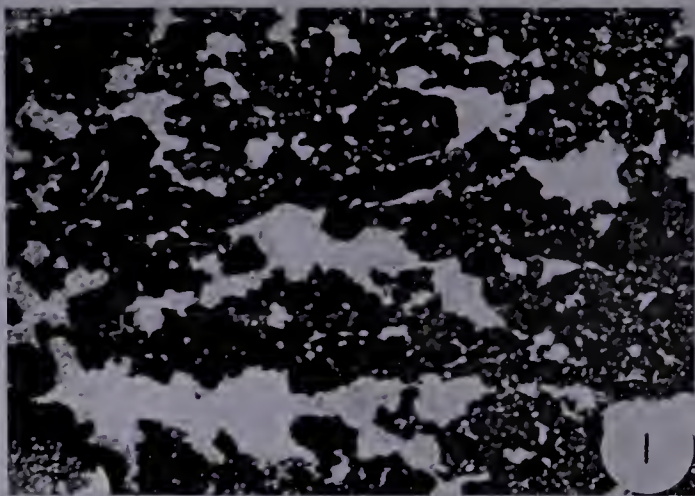
- Figure 1. Photomicrograph: Algal lumps cemented by radially orientated spar cement. Note the internal cellular structure and pellet-lump encrustation. (X6)
- Figure 2. Photomicrograph: Pellets (algal?) showing faint concentric structures. (X62.5)
- Figure 3. Photomicrograph: Same slide as figure 1 (X-nicols). Note the radial fibrous cement around each grain. (X10)
- Figure 4. Photomicrograph: Spar filled cavity within a pellet limestone. Note the apparent enlargement of the cavity. (X62.5)
- Figure 5. Photomicrograph: Lump-pellet limestone. Many of the grains have a circular central spar-filled cavity suggesting an algal origin. The darkened grains are bituminous and hematitic. (X25)
- Figure 6. Photomicrograph: Relict lump-pellet limestone texture. The original texture is still recognizeable although the grains have been completely replaced by dolomite. (X25)
- Figure 7. Photomicrograph: Relict lump limestone texture. Compare with Figure 1. (X25)
- Figure 8. Photomicrograph: Skeletal grains selectively dolomitized and leached. Grey areas represent partially dolomitized spar cement. (X10)



EXPLANATION OF PLATE III

Petrography

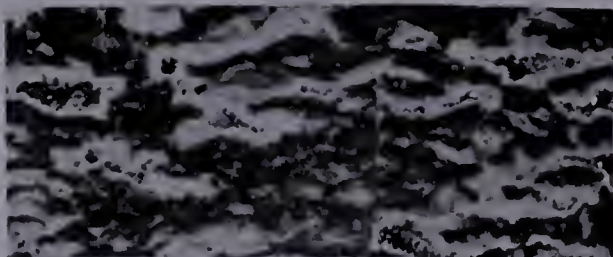
- Figure 1. Photomicrograph: Laminoid fenestral carbonate. The matrix consists of pellets and lumps composed of cryptocrystalline carbonate. The birdseyes are filled by fibrous and granular cement. (X10)
- Figure 2. Photomicrograph: Dolomite (clear white) has selectively replaced the spar cement in the birdseyes. (X12.8)
- Figure 3. Photomicrograph: Laminoid fenestral carbonate. Birdseye texture is preserved even though the rock has been completely dolomitized. The black dots are air bubbles. (X6)
- Figure 4. Photomicrograph: Laminoid fenestral carbonate: Algal cellular structure and birdseyes have been replaced by clear dolomite crystals, and the matrix by dark cryptocrystalline dolomite. (X10)
- Figure 5. Photomicrograph: Crinoidal microfacies. Poorly sorted dolomite matrix containing crinoid fragments. (X10)
- Figure 6. Photomicrograph: Laminoid fenestral carbonate. Fine crystalline dolomite with bands and birdseyes of lighter somewhat coarser crystalline dolomite. (X6)
- Figure 7. Photomicrograph: Lump-pellet limestone. The larger bituminous lumps are selectively dolomitized. (X67.5)
- Figure 8. Photomicrograph: Discrete dolomite rhombs replacing a lime mud. (X10)



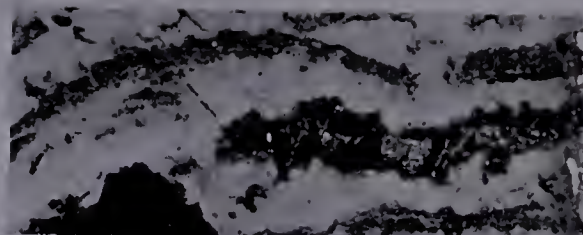
EXPLANATION OF PLATE IV

White Dolomite Replacement

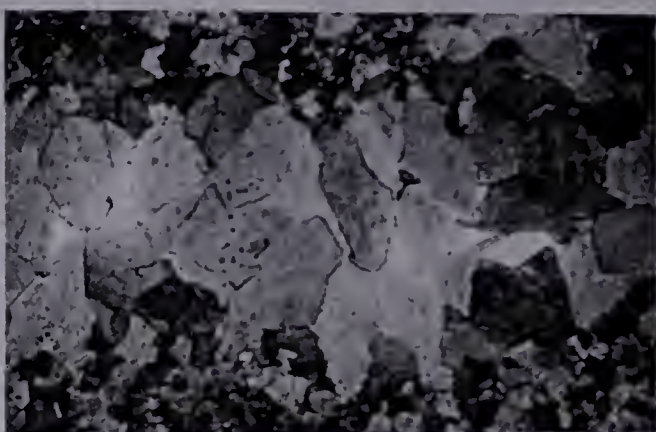
- Figure 1. Polished section: Laminar or banded texture. Horizontal crenulated white dolomite bands replacing a finely crystalline dark brown dolomite. Distribution of the white dolomite suggests an algal origin. (X1)
- Figure 2. Polished section: Laminar or banded texture. White dolomite extensively replacing host dolomite. (X1)
- Figure 3. Photomicrograph: Coarse white dolomite infilling a vug and partially replacing the host dolomite at the margins. (X10)
- Figure 4. Polished section: Polka-dot texture. Round blebs of white dolomite randomly dispersed within a medium crystalline dolomite. (X1)
- Figure 5. Polished section: Birdseye texture grading to a laminar texture. Thin stringers and round blebs of white dolomite horizontally orientated within a medium crystalline dolomite. (X1)
- Figure 6. Polished section: Birdseye texture. White dolomite blebs with similar form, shape and size as the birdseyes encountered in the limestones. (X1.3)
- Figure 7. Slabbed core: Vugular texture. White dolomite occurs as thin linings surrounding irregular shaped vugs. (X0.33)
- Figure 8. Slabbed core: Laminar-marbled texture. Note the replacement of shell fragments near the top. (X0.33)
- Figure 9. Core: Massive stromatoporoid replaced by white dolomite. (X1)
- Figure 10. Polished section: Vugular texture. White dolomite occurs as thin linings surrounding vugs, and void fillings. The host dolomite becomes appreciably darker at the margins of the white dolomite. (X1)
- Figure 11. Surface section at Pine Point, N.W.T., Canada: Presqu'ile dolomite with white dolomite surrounding large vugs. The structure has been interpreted by Beales and Jackson (1966) to be an evaporite solution breccia. Photographs courtesy S.A. Jackson.



1



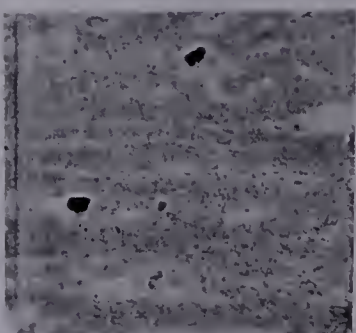
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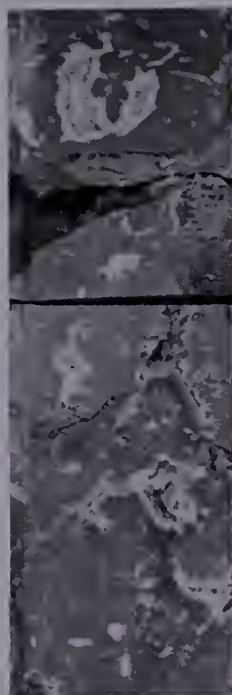
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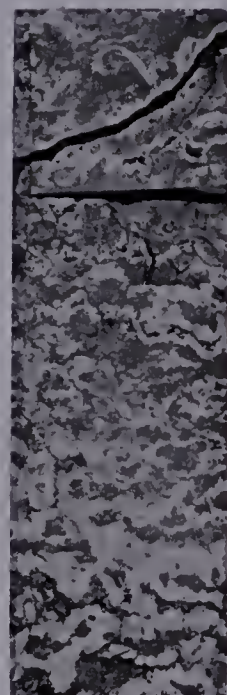
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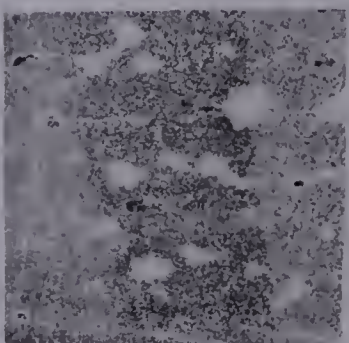
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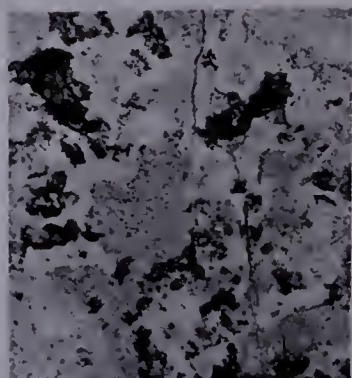
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11a



11b

PLATE IV

EXPLANATION OF PLATE V

Rock Types

- Figure 1. Slabbed core: Nodular anhydrite of the Muskeg Formation.
(X0.33)
- Figure 2. Slabbed core. Stromatoporoid detritus microfacies. Bed containing coral fragments.
(X0.33)
- Figure 3. Slabbed core: Crinoidal microfacies. Crinoids and Thamnopora fragments within a matrix of medium crystalline dolomite.
(X0.33)
- Figure 4. Slabbed core: Stromatoporoid detritus microfacies. Partially leached stromatoporoid fragments and scattered skeletal debris.
(X0.33)
- Figure 5 & 6. Slabbed core: Laminoid fenestral carbonate. Birds-eye textures grade into laminar (color banded) dolomite.
(X0.33)
- Figure 7. Slabbed core: Laminoid fenestral carbonate. Dolomite with desiccation voids and fractures.
(X0.33)
- Figure 8. Slabbed core: Stromatoporoid detritus microfacies. Typical texture showing partially leached stromatoporoid fragments.
(X0.33)
- Figure 9. Polished section: Stromatolite microfacies. Alternating calcite rich and bituminous rich laminae.
(X1)
- Figure 10. Slabbed core: Laminoid fenestral carbonate. Dolomite very similar in appearance to the stromatolite microfacies. Probably formed by algal mats.
(X0.33)
- Figure 11. Polished section: Laminoid fenestral carbonate. Limestone laminae composed of pellets and lumps. Note the vertical desiccation (?) fractures and the large algal lump in the upper right hand corner.
(X1)
- Figure 12 & 13. Polished section: Laminoid fenestral carbonate. Dolomite with leached vugular porosity. Voids are interpreted to have formed by shrinkage.
(X1)



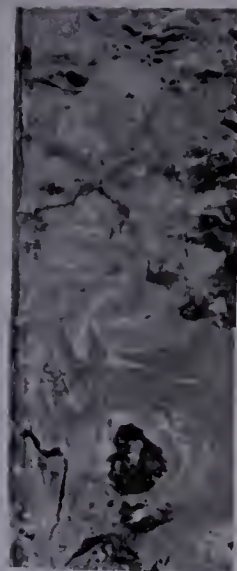
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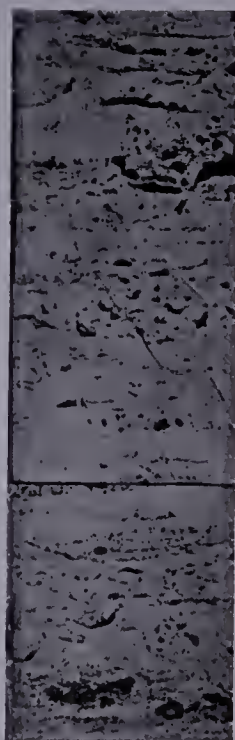
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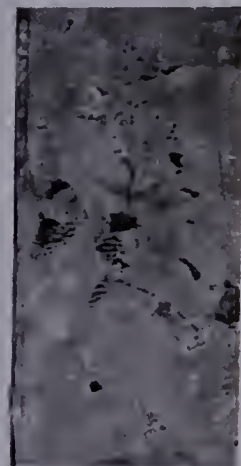
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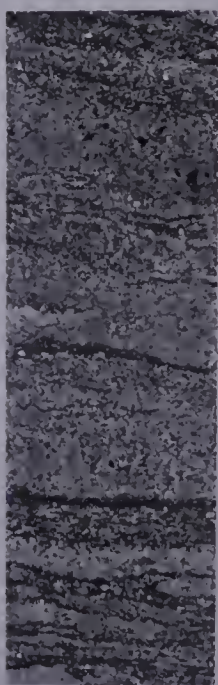
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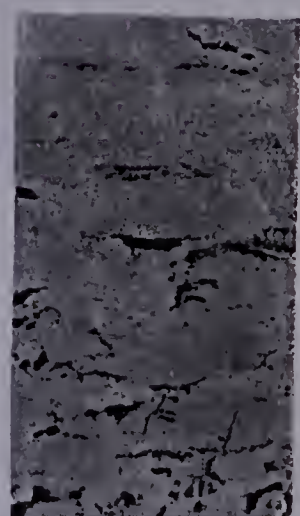
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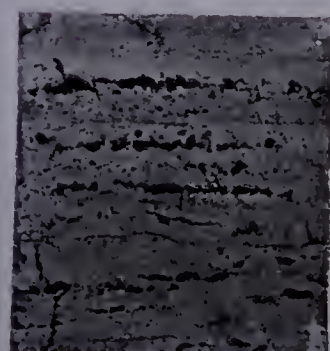
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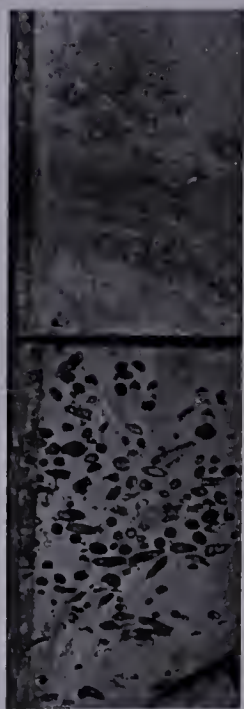


13

EXPLANATION OF PLATE VI

Rock Types

- Figure 1. Slabbed core: Leached skeletal (amphiporoid) dolomite. Typical leached vugular porosity of the lagoonal facies, thought to represent leached amphiporoid stalks. (X0.33)
- Figure 2 & 3. Polished section and slabbed core: Dolomite breccia. (X1 and X0.33 respectively)
- Figure 4. Slabbed core: Stromatoporoid microfacies. Highly fractured medium crystalline dolomite containing fragments of stromatoporoids. (X0.33)
- Figure 5. Polished section: Medium crystalline (pellet) dolomite. Typical vugular and pinpoint porosity associated with these rocks. (X1)
- Figure 6. Core: Skeletal dolomite microfacies. Skeletal material commonly represented only by leached skeletal porosity. (X1)
- Figure 7. Slabbed core: Skeletal dolomite microfacies. Fragmented skeletal remains, commonly replaced by white dolomite. Large concentric structure is interpreted to be an algal growth. (X0.33)
- Figure 8 & 9. Slabbed core: Gastropod conglomerate. Bed consisting entirely of gastropods. (X0.33)
- Figure 10. Slabbed core: Fine crystalline (lime mud) dolomite. Slightly mottled and stylolitic, finely crystalline dolomite typical of the lagoonal facies. Upper portion of the core is anhydritic and argillaceous. (X0.33)



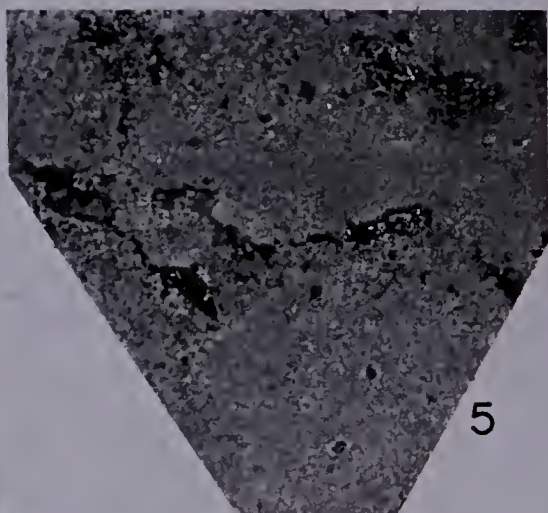
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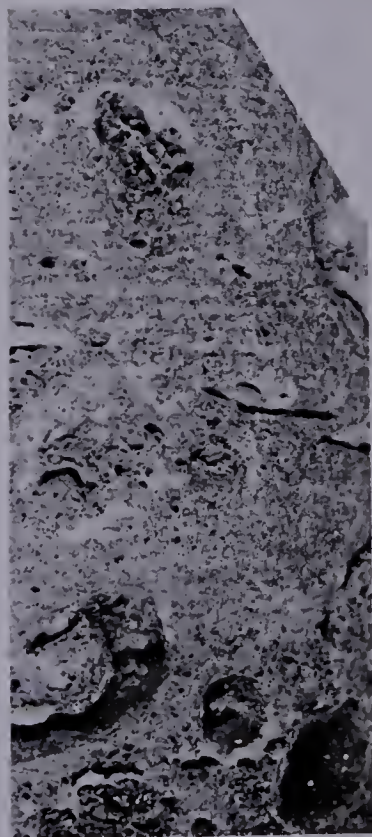
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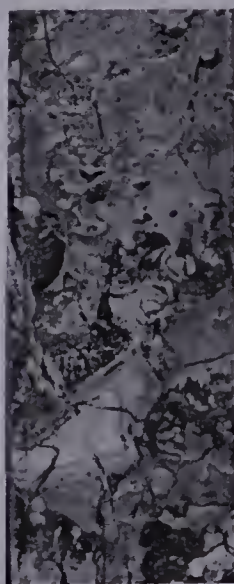
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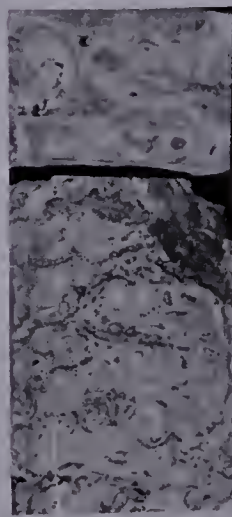
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PLATE VI.

APPENDIX

WELLS USED IN PRESENT STUDY

Well Location	K. B.	Keg River Formation Elev.	Keg River Formation Thickness	Chinchaga Formation Elev.	Black Creek Member Elev.
4-31-105-7 W.6	2103	7028	292	7320	--
11-35-105-7 W.6	2142	7032	278	7310	--
13-36-105-7 W.6	2148	6888	417	7205	--
13-17-106-8 W.6	1974	6455	583	7038	--
6-3-107-6 W.6	1754	6197	543	6740	--
2-16-107-6 W.6	1755	6210	530	6740	--
16-18-107-6 W.6	1774	6265	655	6920	--
13-20-107-6 W.6	1723	6290	540	6830	--
11-10-107-7 W.6	1872	6390	720	7110	--
8-11-107-7 W.6	1969	6580	390	6970	--
10-11-107-7 W.6	1616	6328	710	7038	--
7-15-107-9 W.6	1668	6382		N.P.	--
13-20-107-9 W.6	1608	6278	762	7040	--
16-26-107-9 W.6	1612	6077	903	6980	--
2-32-107-9 W.6	1596	6550	412	6962	--
6-29-108-5 W.6	1698	5930?	598	6528?	--
16-34-108-5 W.6	1638	5690	655	6345	--
4-31-108-6 W.6	1616	5912	647	6559	--
4-16-108-7 W.6	1635	6382	336	6718	6286
8-28-108-7 W.6	1618	5865	771	6636	--
3-32-108-7 W.6	1595	5826	739	6565	--
10-32-108-7 W.6	1595	5940	682	6622	--
11-27-108-8 W.6	1584	5868		N.P.	--

Well Location	K. B.	Keg River Formation Elev.	Keg River Formation Thickness	Chinchaga Formation Elev.	Black Creek Member Elev.
12-29-108-8 W.6	1586	5922	885	6807	--
3-5-108-9 W.6	1574	6050	936	6986	--
10-7-109-4 W.6	1493	6470	680	6150	--
9-18-109-5 W.6	1579	5910		N.P.	--
10-20-109-6 W.6	1514	5572		N.P.	--
2-28-109-6 W.6	1511	5649	641 est.	6290 est.	--
11-28-109-6 W.6	1474	5524	726	6250	--
2-4-109-7 W.6	1590	6140	434	6574	--
10-5-109-7 W.6	1579	5760	810	6570	--
11-6-109-7W.6	1574	5783?		N.P.	--
7-18-109-7 W.6	1552	5656	937	6593	--
13-2-109-8 W.6	1572	5798	862	6660	--
1-3-109-8 W.6	1570	5840	830	6670	--
3-3-109-8 W.6	1580	5850	776	6626	--
12-3-109-8 W.6	1595	5836		N.P.	--
4-9-109-8 W.6	1603	6289	413	6702	--
A3-10-109-8 W.6	1590	5909	757	6662	--
10-10-109-8 W.6	1591	5797	915	6712	--
12-10-109-8 W.6	1606	5852	870	6722	--
4-15-109-8 W.6	1599	6270	387	6657	--
16-15-109-8 W.6	1586	5766	916	6682	--
9-24-109-8 W.6	1553	6212	310	6522	5940
2-28-109-8 W.6	1641	6368	299	6667	6215
12-28-109-8 W.6	1694	6394	320	6714	--
2-31-109-8 W.6	1752	6495	295	6790	6415

Well Location	K. B.	Keg River Formation Elev.	Keg River Formation Thickness	Chinchaga Formation Elev.	Black Creek Member Elev.
2-32-109-8 W.6	1728	5872	878	6750	--
7-32-109-8 W.6	1744	5866	904	6770	--
10-32-109-8 W.6	1773	5900	878	6778	--
12-33-109-8 W.6	1750	6348	400	6748	--
10-27-109-9 W.6	1769	6565	290	6855	6322
10-6-109-10 W.6	1700	6706	344	7050	--
6-34-109-10 W.6	1798	6609	381	6990	--
6-29-110-4 W.6	1294	5135	603	5738	--
10-13-110-5 W.6	1317	5124	716	5840	--
8-9-110-6 W.6	1440	5785	352	6137	--
1-8-110-7 W.6	1680	5865?	687	6552	--
2-8-110-8 W.6	2010	6664	312	6976	6550
3-12-110-8 W.6	1830	6113	620	6753	--
9-13-110-8 W.6	1956	6017	689	6506	--
2-18-110-8 W.6	2095	6286	800 est?	N. P.	--
5-29-110-8 W.6	2181	6360	733	7093	--
4-2-110-9 W.6	1932	6687	287	6974	6491
6-33-110-10 W.6	1314	5645	827	6472	--
7-13-110-11 W.6	1472	6178	507	6685	--
6-28-111-4 W.6	1168	4800	610	5410	--
4-10-111-6 W.6	1638	5774	473	6247	--
9-21-111-6 W.6	1120	4920	774	5694	--
13-11-111-7 W.6	1510	5410		N. P.	--
4-21-111-8 W.6	1158	5570	443	6013	--
10-8-111-9 W.6	1230	5255	945	6200	--
4-14-111-9 W.6	1204	5148	994	6142	--

B POOL WELLS EXAMINED

Well Name and Location	K.B.	Platform Elevation	Top of Rainbow Member (Logs)			Cored Interval Logged
			Elev.	Upper Subsea	Regional removed Elev.	
Banff Mobil Rainbow West 13-2-109-8 W.6	1572	6520	5798	-4226	-4254	6150 5515-6153
Banff Mobil Rainbow West 1-3-109-8 W.6	1570	6550	5840	-4270	-4278	6190? 5832-6132
Banff Mobil Rainbow West 3-3-109-8 W.6	1580	6506	5850	-4270	-4270	6204 5900-6550
Banff Mobil Rainbow West 12-3-109-8 W.6	1595	N.P.	5836	-4241	-4245	N.P. 5840-6142
Banff Mobil Rainbow West A3-10-109-8 W.6	1590	6517	5909	-4319	-4337	6157 5933-6169
Banff Mobil Rainbow West 10-10-109-8 W.6	1591	6550	5797	-4206	-4236	6145 5792-6156
Banff Mobil Rainbow West 12-10-109-8 W.6	1606	6590	5852	-4246	-4269	6132? 5841-6180
Banff Mobil Rainbow West 4-15-109-8 W.6	1599	6524	6270	-4671	-4703	6270 No Core
Banff Mobil Rainbow West 16-15-109-8 W.6	1586	6543	5766	-4180	-4238	6110 5762-6667

INTER REEF WELLS EXAMINED

Well Name and Location	K. B.	Elevation of Keg River		Elevation Muskeg Formation	Elevation Black Creek Member	Cored Interval Logged
		Upper Member	Lower Member			
Banff Mobil Rainbow West 9-24-109-8 W.6	1553	6212	6385	5510?	5940	5902-5961
Banff Mobil Rainbow West 2-28-109-8 W.6	1641	6370	6534	5705	6215	6366-6412 & 6507-6522
Imp. Black Creek 10-27-109-8 W.6	1769	6566	6720	5880	6325	6694-6719

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